Setting a foundation for the development of medication dosage calculation problem solving skills among novice nursing students

The role of constructivist learning approaches and a computer based 'Authentic World' learning environment

(APPENDICES)

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APPENDICES

Appendix Ii

A discussion and evaluation of relevant literature regarding the problem of medication dosage calculation errors committed in clinical practice and by health care professionals during written tests

Definitions and classifications of medication administration errors

Early research in this area was performed by Barker and McConnel (1962) who defined an error in medication as :

> The administration of the wrong medication or dose of medication, drug, diagnostic agent, chemical, or treatment requiring the use of such agents, to the wrong patient or at the wrong time, or the failure to administer such agents at the specified time or in the manner prescribed or normally considered as accepted practice (Barker and McConnel 1962, p.95).

In an effort to provide a benchmark for classification purposes, the American Society of Hospital Pharmacists (ASHP 1982) developed standard definitions of medication error categories. The key elements of which were outlined by Allan and Barker, (1990, pp.558-560), and include two categories which specifically involve errors associated with miscalculation of medication dosages and rate of intravenous administration of fluid, and one category which involves potential errors:

- **Wrong-dose error**

When the patient receives an amount of medicine that is greater than or less than the amount ordered. Barker *et al* (1984) suggested that any allowable deviation error range should be based on the greatest variation typically allowed by the hospital, in its selection of the measuring devices routinely provided to the nurse (e.g., oral syringe, measuring cup). Allan and Barker (1990) suggested that ±17% is an allowable deviation for measured oral liquid doses, whilst Chafetz and Hodges (1965) suggested that the administration of a half tablet obtained by splitting the tablet should be considered a wrong dose, because of evidence that the active drug is unevenly distributed within each tablet. Nevertheless despite the move toward 'unit-dose measures', there remain many occasions when nurses need to use proportional-reasoning to calculate oral and injection route dosages. This due to the non-availability of appropriate dispensed dosages, e.g., a common initial oral dose of the ACE inhibitor drug Captopril is 6.25 milligram, however the smallest available tablet is 12.5 milligram. The range of computational skills commonly required for calculating medication dosages are reviewed in Section 1.5.

- **Wrong-rate-of-administration errors**

These occur with infusions of intravenous fluids or liquid enteral products. Within the health care trusts in the study site region it was a policy that infusions containing additives such a potassium chloride or any drug, was infused via an electronic pump. There are a wide range of commercial pumps available and these are commonly set at millilitres per hour to be infused, however this varies from pump to pump. The flow rate of infusions which do not contain additives is usually calculated by computation of drops to be administered per minute. Subsequently the range of computation skills commonly required for calculating intra-venous infusions are reviewed in Section 1.5.

- **Potential errors**

The ASHP coined the term potential errors to define 'prevented errors'. Within its guidelines the ASHP argue that a medication error is not an error until the mistake reaches the patient. That means that a prescribing error by a medical practitioner, or a dispensing error by a pharmacist is not an error until it is administered to the patient. This definition clearly has implications for nurses who 'administer the majority of medications in the hospital setting'. The United Kingdom Central Council (UKCC) for Nursing, Midwifery and Health Visiting (1992, p.3; 2000, p.3) stated that the administration of medicines requires thought and the exercise of professional judgement which is directed to factors including: confirming the correctness of the prescription and judging the suitability of administration at the scheduled time of administration. Subsequently as will be discussed presently, it is essential that registered nurses develop accurate conceptual models of the dosage problems they are attempting to solve.

However in contrast to the ASHP, Hynniman *et al* (1970) used only three main categories of medication errors, i.e.:

- **Commission**

Defined as any dose incorrectly administered

- **Omission**

Defined as any dose that should have been administered but was not

- **Discrepancies**

Defined as any inconsistency or breakdown in the functioning of the drug distribution system which did not result in an error of commission or omission.

Allen and Barker (1990) concluded that the lack of operational definitions of terms such as those used by Hynniman *et al*, means that comparability with other studies is limited. Moreover despite the range of published research in this area, Gladstone (1995) reported that there remained confusion amongst nurses regarding the definition of drug errors and the appropriate actions to take when they occurred. Ultimately it is clear from available definitions that a wide range of 'medication errors' potentially occur in clinical practice. However this thesis concentrates specifically on that component of medication errors potentially occurring through 'miscalculation of dosage'.

Calculation of error-rate

Barker *et al* (1966) devised a formula for calculating the frequency of medication error rate :

$$\text{Frequency} = \frac{\text{No. of errors}}{\text{No. of opportunities for error (OE)}} \times 100\%$$

Medication error rate is calculated as the number of actual errors (incorrect in one or more ways), divided by the total opportunities for error. This figure is then multiplied by 100, to arrive at a percentage. The term 'opportunity for error' was coined for use as the basic unit of data in medication error studies. Thus an opportunity for error includes any dose given plus any dose ordered but omitted. Moreover any dose given can only be correct or incorrect (within the operational definitions of medication error); hence this definition prevents the error rate exceeding 100%. Therefore the definition of the total opportunities for error must be carefully stated in a study; this to ensure accurate calculation of the true medication error rate (Allan 1987). Allan and Barker (1990) argued that if salient errors (e.g. omission errors) are not included in the denominator of the equation used to calculate the error rate, then reported rates are likely to be overestimates.

Reported incidence and effects of medication dosage calculation errors in clinical practice

One of the earliest documented reports of 'graduate nurses having much difficulty with math calculation' was made by Faddis (1939, p.1217) who concluded that in respect of medication errors 'nurses are like other human beings and mistakes are sometimes made in spite of all precautions'. Unfortunately over sixty years later medication dosage calculation errors continue to occur amongst a range of health care professionals. Moreover the number of medication errors reported at each hospital probably represent only the 'tip of an iceberg' (Hackel *et al* 1996, Cooper 1995, Gladstone 1995). Schwartz and Jackson (1980, p.23) concluded that 'computational skills, necessary for the safe administration of medications, continue to be a key concern for both nursing education and nursing practice'.

However van Leeuwen (1994) argued that although medication error rates seem a plausible indicator, it is not a foregone conclusion that error rates are good barometers of quality. Thus currently measured error rates represent a process within an organisation and can range from no or few errors to substantial errors, with the variation reflecting a variety of scenarios. Hence hospitals that do not measure error rates obviously report no errors. Inattention to, or a lack of clear methods to collect and define errors can also result in no reported errors or low error rates. In contrast however, a hospital that standardises and implements a measurement scheme may have high reported error rates. Therefore there is a necessity for caution when interpreting error rates reported in the range of published literature.

One health care trust within the study site region operated a non-punitive policy toward medication errors unless evidence of professional misconduct or negligence was apparent. This policy was implemented to encourage reporting of medication incidents. An analysis of reported incidents over a 3 year period indicated that of 445 medication incidents, 5% (22 errors all involving overdoses), were associated with calculation errors made by nurses. However it is important to recognise that as the hospital reporting system did not include an opportunity for error calculation, that this error rate should not be mistaken for the frequency of errors occurring within the Trust. Nevertheless of the 22 errors reported, all amounted to administration of from twice to 10 times the prescribed dose. An example of a reported error was 2000 micrograms of diamorphine (heroin) being administered instead of the 200 micrograms prescribed. An error of 10 times the prescribed dose. Hence while reported incidents were relatively rare it was the potential gravity of such incidents which caused concern to both clinical and education staff at the study site. Therefore it was incumbent upon the college, as an education provider, to take all reasonable steps to prepare nursing students to develop relevant medication dosage calculation problem solving skills. Ultimately it was the drive for safety that fueled this investigation.

In a wider context a review of the international literature suggested that the incidence of medication dosage errors is greater in the USA than the UK. However as previously indicated this may be due to variations in reporting systems. Rosati and Nahata (1983) cited previous studies which highlighted the incidence of medication errors over the preceding two decades, as between 0.64% and 25.9%. Thiele (1986) reported that error rates range from 5% to 20% of all medications administered in hospitals; with miscalculation of drug dosages accounting for 12% of all errors, while Barker *et al* (1984) offered a rough summary which indicated that the medication error rate in hospitals of the USA was approximately one error per patient per day.

In an observational study of nine registered nurses in the USA, Barker and McConnell (1962) reported that of 572 medications administered, there were a total of 93 unreported or unknown errors, of which: 6 of 9 nurses administered underdoses (total 12, i.e. 13% of total errors), and 4 of 9 nurses administered overdoses (total 6, i.e. 8% of total errors). The authors concluded that the error ratio for the safest nurse was 1 : 13, for the average nurse approximately 1 : 6, and for the nurse making the greatest proportion of errors between 1 : 3 and 1 : 4. Girotti *et al* (1987) observed nurse medication administration errors, amongst 60 consecutive patient admissions to an adult ICU facility. During 4581 administrations the authors reported 102 errors, i.e. an error rate of 2.2%. Error type analysis indicated that administration of a wrong dose accounted for 12.7% of the errors.

Dean *et al* (1995) compared medication errors in a hospital in the United States and a hospital in the United Kingdom. In the U.S. and U.K. hospitals, 919 and 2756 opportunities for error were observed respectively. The medication error rate in the U.S. hospital was 6.9%, over twice the 3.0% rate observed in the U.K. hospital. Incorrect doses and unordered doses were the most common error types in the U.S. hospital. Omitted doses and incorrect doses were the most common types of errors in the U.K. Ferner and Whittington (1994) reported the coroner's cases of death due to errors in prescribing or giving medications in Birmingham, UK between 1986-1991. The authors concluded that about one fifth of deaths within this category were due to dosage errors, however the personnel involved were not categorised.

Ridge *et al* (1995) covertly observed 37 nurses (grade C to G) during the performance of 74 single nurse drug rounds, at a NHS trust hospital in the UK. Reported results indicated that during 3312 drug administrations, 115 errors occurred, a 3.5% error rate, of which there were 17 wrong doses, i.e., 4 greater and 13 less than the prescribed dose respectively. During a 1-year study period Lesar *et al* (1997) reported identification of 2103 medication errors, of which 696 had the potential for adverse patient effects, the overall rate of errors being 3.99 errors per 1000 medication orders. The miscalculation of decimal points, or unit and rate expression factors contributed 17.5% (122) of the errors.

The necessity for accurate drug dosage calculation is most critical in the area of child health, Kennedy (1996) stating that,

> The high acuity of hospitalized pediatric patients requires well-articulated safety measures in medication dosing and administration. Simple arithmetic errors in calculating medication and fluid requirements can occur easily. A decimal point error could mean injury to a child because of the fine line between therapeutic and toxic effects of medications (Kennedy 1996, p.295).

Koren and Haslam (1994) stated that tenfold errors in paediatric doses are not uncommon. Hence because the needed volume of stock solution is generally small, even a tenfold higher volume may still appear deceivingly normal. In a prospective study Olsen *et al* (1997) registered iatrogenic medication errors among paediatric admissions at a large Swedish hospital. The two most common causes of incidents were neglecting to give a medication on schedule and administration of an incorrect dose. Raju *et al* (1989) undertook a four year analysis of iatrogenic medication errors reported in paediatric ICUs at a large university hospital in the USA. The authors reported 315 medication errors among 2147 admissions, of which 60.3% were attributed to nurses, and included error categories of wrong rate (43, i.e., 13.7%) and wrong dose (43, i.e. 13.7%). Resultant patient injuries included 33 potentially serious injuries, 32 mild injuries and 1 substantial injury. Ultimately whilst the authors do not provide specific details of the type of calculation errors performed by nurses, they cite improper placement of the decimal point as the commonest error in calculation amongst physicians.

This latter point was highlighted vividly by the Daily Mail report, (Wednesday January 29 1997), which cited the administration to a 3½lb premature baby of a fatal 15 mg dose of morphine, instead of 0.15mg (100 times the recommended dose), by a junior doctor in the UK. The coroner was cited as stating that

> There has been a deplorable failure in the standard of maths in this country. It's a cause of very considerable concern that in the 1990s universities are producing graduates incapable of making that sort of calculation without the aid of a calculator (Daily Mail Jan 29 1997, p.1)

The implications of misplacing a decimal point within a computation can result in tragedy for both patients and health care professionals alike. However any discussion of the phenomenon of dosage calculation errors must include the issue of prescription writing. Baker and Napthine (1994) reviewed a range of literature which suggests that nurses are commonly blamed for medication errors when 'it is the system which should be examined'. Baker and Napthine argued that 'the system' has placed great emphasis upon the need to follow the procedure of the institution. This in the belief that if only everyone would follow the procedure, errors would not occur. In respect of advice on prescription writing, the British National Formulary (2000, p.4) states that:

- For solids, quantities of 1 gram or more should be written as 1 g, etc.
- Quantities less than 1 gram should be written in milligrams, e.g. 500 mg, and not 0.5 g.
- Quantities less than 1 mg should be written in micrograms, e.g. 100 mcg, not 0.1mg.

However as part of the current investigation, during visits to the clinical areas of five hospitals across three counties it was clear that some doctors were not adhering to these guidelines, and nurses were required to make a range of both weight and volume conversions. That is, while the pharmacy departments dispensed medications labelled with the appropriate SI unit, e.g., 625 micrograms, the doctors provided a written prescription for 0.625 mg. Where the ward pharmacist discovered this, an appropriate annotation to the prescription chart was made. However where this had not been identified, the administering nurse had to convert between the SI units. Subsequently as will be discussed in section 1.5, it is essential that nursing students are adequately prepared to perform the range of SI unit conversions that are commonly encountered in clinical practice.

Performance of registered nurses and other health care professionals on written medication dosage calculation assessments

Rolfe and Harper (1995) investigated the ability of 150 UK hospital based doctors to convert between mass concentrations, dilutions and percentage concentrations. Around half the doctors surveyed were unable to convert drug doses correctly from a percentage concentration or dilution to the more conventional mass concentration; answers varying by as many as three orders of magnitude.

Perlstein *et al* (1979) undertook a two phase study in the USA, designed to expose computation errors among a range of health care professionals. *Computation* presumably taken to include both arithmetical operations and problem solving ability, however the authors do not make this explicit. Phase 1 involved 27 registered nurses who were provided with 10 calculations, each presenting a simulated physician's written drug order specifying the weight of a newborn infant and the concentration of the stock solution of drug available. Reported results indicated that 56% of identified errors represented ±10 times the ordered dose. The second phase amongst 95 registered nurses revealed that 1:12 answers represented ± 10 times the ordered dose. Similar to the reports of Raju *et al* (1989) and The Daily Mirror (1997) the most frequent computation errors were associated with misplacement of decimal points. The study indicated that calculation errors were compounded by an additional inability (at both nursing and physician level) to judge the appropriateness of a drug order. Commenting on the use of calculators the authors suggested that calculators do not provide a self evident solution to the problem of preventing decimal point errors, made by personnel who are not equipped to judge consistently the reasonableness of their mathematical results. This important issue will be returned to in the ensuing chapters of this thesis.

Conti and Beare (1988) compared the performance of 55 registered nurses during a basic mathematics/drug calculation test with the number of medication administration errors subsequently committed during a 12 month period. Subjects were given a 41 item drug calculation test requiring 100% accuracy, and were then observed in clinical practice to determine reported medication errors. Test scores ranged from 12-41 (mean 37), with only 11 (20%) of nurses achieving 100%. Thirty one nurses committed a total of 66 errors in clinical practice, 11 involving administration of incorrect dosages. The authors concluded that statistical analysis indicated that there was no association between raw test score and the incidence of subsequent medication errors. Thus the authors reasoned that

> A mathematics/drug calculation test cannot be used as a reliable tool to screen those individuals most likely to make the type of medication errors most frequently reported (p. 58).

Conversely studies from both the USA and the UK indicated that experience in clinical settings did not significantly improve subsequent performance on written medication dosage calculation assessments (Bayne and Bindler 1988, Laverty 1989). These latter findings support those from the 'situated learning' literature. Most notably Lave (1988) in her seminal work described how 'just plain folk' could not transfer perfectly adequate computation skills used during grocery shopping, to the solving of formal word problems. I will return to the critical importance of situated cognition and situated learning later.

These reported findings clearly reinforce the existence of a theory-practice divide. That is abstract classroom- and word-based assessments that are not specifically linked to contextual features that exist in clinical practice appear to be an unreliable indicator of clinical performance. Conversely clinical experience of medication administration does not appear to positively influence performance on written medication dosage calculation assessments. More recent research by the Mathematical Sciences Group involving registered nurses and other professional groups in the UK, indicated that

> ...most adults make sense of situations in ways which differ quite radically from those of mathematicians. Rather than having a mathematical orientation which strives toward consistency and generality, problem solving in working life is geared to pragmatic concerns and solving particular problems - a mode we term everyday orientation.
>
> (Noss *et al* 1998, p.3)

Noss *et al* argued that despite the fact that mathematical orientations can provide a powerful way to understand a range of physical, biological, economic and social phenomena, that non-mathematicians commonly seem unable to draw on their everyday orientations in order to construct mathematical orientations.

Given the problems observed at the study site, I was intrigued by the reported unreliability of paper based tests to predict dosage calculation performance in clinical practice; and the apparent inability of many adults to perform the 'reverse operation' of utilising experience to construct a generalisable mathematical orientation. In essence why were otherwise intelligent individuals seemingly unable to link classroom-based abstractions with practice, or practice with theory/abstractions? Moreover what was it about health professional education systems across a range of continents that appeared unable to narrow the gap between college theory and clinical reality? In this instance the theory-practice divide represented more than a mis-match of college values with clinical reality. It potentially represented a lethal cocktail of circumstances that combined to create a patient safety issue.

Given the critical effects of dosage calculation errors committed in clinical practice, there is a requirement that students in the health care professions are formally assessed in this area by their respective professional education establishments. This is underlined by the United Kingdom Central Council (UKCC), for Nursing, Midwifery and Health Visiting (1986, p.47) statement that

> registration protects the public by indicating that the practitioner is safe and competent to practise.

This being affirmed through the learner's achievement of the outcomes designated in the Nurses, Midwives and Health Visitors Approval Order, Rule 18A (2), Statutory Instrument 1989, No. 1456; via which the Welsh National Board (WNB), for Nursing, Midwifery and Health Visitor Education (2000), has stated that with regard to *Care Delivery*, and as part criteria for assessment of safety, nursing students must demonstrate ability in calculation, handling, administration and storage of drugs (WNB 2000, p.55)

Therefore nurse education establishments must take all reasonable steps to both develop and assess the acquisition of relevant professional skills among their student body. This to ensure that they can function as safe practitioners during medication administration, and in other relevant elements of professional nursing practice which require the application of numerical concepts. I intend to set out and illustrate the construction of a theory which explains one method of more closely aligning this complex theory-practice divide. As a starting point in this process, Section 1.5 and Appendix lii discusses and evaluates literature regarding the range of computational skills used during the calculation of fundamental medication dosages.

Appendix Iii

A review and evaluation of literature regarding the range of computations utilised during the calculation of medication dosages

Numeracy

Withnall et al (1984, p.1) claimed that the term 'numeracy' seems to have been first publicly used in the Crowther Report (1959), as meaning

> The minimum knowledge of mathematics and scientific subjects which any person should possess in order to be considered educated

Such a claim is value laden and of little practical use when considering a definition of numerical ability that could be operationalised for measurement purposes. Chenger *et al* (1988) argued that it is crucial that nurses possess the knowledge and skills to perform calculations (computations) and the more complex problem-solving skills involving formulae, since such skills are needed to ensure that the patient receives the correct dosage of medication. Within this context Das (1988) defined arithmetical achievement has having two identifiable parts:

> *Computational ability* [the carrying out of calculations/arithmetic operations, i.e. addition, subtraction, multiplication and division of integers etc.], and *The ability to solve problems* [understanding the logic of a problem; and utilizing processes which involve coding of information into a unitary representation which is gestaltic or quasi-spatial in nature] (Das 1988, p.101).

Given both the relevance of the Das (1988) definition to the learning of medication dosage calculation skills, and the ability to operationalise the definition into computation and conceptual problem-solving skills, it was selected as the standard definition used within this thesis.

Whilst key numeracy skills are required for safe medication dosage calculation, they are further required for many aspects of professional nursing practice, and the relevant theory which underpins it. This section draws on three studies which produced inventories of the mathematical concepts utilized in clinical nursing practice. Those elements that are specific to the calculation of medication dosages are identified, as a precursor to a discussion of the selection numeracy assessment and the fundamental medication dosage calculation assessment employed at the study site.

A review of the use and application of numerical concepts in the theory and practice of nursing

Three studies of the mathematical concepts utilised in clinical nursing practice have been undertaken between 1982 and 1998. The first study was undertaken by Pirie (1982, 1987) in the United Kingdom. Pirie surveyed the views of 150 clinical nurses, utilising participant observation and an informal interview strategy, and reviewed 'maths for nurses' textbooks to compile a taxonomy of mathematical skills. Pirie placed an emphasis upon identifying mathematical concepts used within clinical nursing practice, or implicitly required to pass final state nursing examinations. Twenty four key mathematics skills areas were identified, the 'upper bounds' of which were set via analysis of responses by 18 nurse tutors to a 'mathematics topics questionnaire'. The completed list was sent to 35 nurse tutors for their comments. Consequently Pirie reported that, discrepancies and comments occurred over topics which the tutors thought unnecessary, but which had, in fact, been observed in clinical practice. Pirie (1987) concluded that this approach underlined the need for a task analysis rather than an 'expert' method, when constructing the taxonomy.

Roberts (1990) conducted research in the USA, to identify the essential knowledge component required for safe nursing care within an acute care hospital. Roberts utilised a Delphi Technique, which involved a series of three rounds to establish consensus among seven nurse education experts regarding requisite curricula content in this area. Panellists identified key categories of curricula content, and ranked the items of each category in order of importance. The responses received were analysed using frequency distributions of the rankings of the votes, and mean and standard deviations, to establish criteria for determining consensus upon what constituted from 'essential' to 'generally unimportant' spheres of knowledge. On the basis of Pirie's observations the predominantly academic role of the 'experts' used in the Delphi process may not have reflected the true range of computational skills used in clinical practice.

The most recent taxonomy was produced by Hutton (1998a) in the UK. Hutton substantially developed the inventory produced by Pirie (1987), and reflected the major changes that had occurred in both clinical practice and nurse education in the intervening sixteen years. One critical contribution of Hutton's study was to identify the nursing mathematics that was either specific to, or generally utilised within the four current branches of nursing, i.e., child, adult, mental health and learning disability branches. This represented a substantial development of Pirie's inventory, which while being a seminal piece of work at the time, provided a rather general overview of nursing mathematics. Hutton interviewed clinical nursing staff and students from all four branches of nursing and relevant clinical settings, to identify their perceptions of the mathematics used in those areas. These findings were then confirmed and enhanced by the processes of observation and shadowing of clinical staff and students in clinical practice.

What follows in Boxes 1 through 3, is a synthesis of the key medication dosage calculation skills identified within the three inventories. Areas where the work of Pirie (1987), Roberts (1990) and Hutton (1998) concurred were:

Box 1

Computational Skills:

- Addition, subtraction, multiplication, and division of whole numbers (up to four digits).
- An understanding of numerator and denominator function in fractions.
- Multiplication, division and simplification of fractions.
- Understanding the concepts of the decimal system / meaning of the decimal place, and not merely memorizing that in multiplication the decimal point is moved to the left and in division the decimal point is moved to the right.
- Multiplication and division of decimals (up to three decimal places).
- Conversions within and between fractions and decimals.
- Understanding the concept of both weight and volume elements of the SI unit system including abbreviations and concepts of equivalency.
- Understanding of the concept of percentage.
- Understanding of the principles underpinning ratio and proportion.
- Understanding and using formulae and multiple computations within formulae.
- Estimation - e.g. the ability to estimate whether 10 times 0.003 is approximately 0.03 vs 3.0 or 0.003.
- Use of a calculator (generally not important).

Box 2

Conceptual Problem Solving Skills:

- The ability to apply basic math skills when given problems. Some problems requiring more than one step to solve.

Box 3

Additional areas specifically identified by Roberts (1990) were:

- Ability to read a medication order and drug label and then extract the important information necessary to set up the problem (essential knowledge).
- Calculating the correct amount of medication to be administered given the label information and the MDs order (essential knowledge).
- An understanding of the difference between dosage of medication and the volume in which that dosage comes (essential knowledge).
- The ability to place numbers correctly in a format for calculation, whether the method be ratio/proportion, dimensional analysis, or desired dose over have on hand, times, volume (essential knowledge).
- Dilutions (essential for paediatric/child specialities).
- Concepts of basic algebra (generally essential).
- Understanding when to round off numbers and when not to in performing math calculations (generally essential).
- A feel of comparison of the quantities, proportions of common units of measures (e.g. cc, conversion of cc to tsp) (generally necessary in the USA).
- A basic working knowledge of normal ranges for commonly administered drugs (e.g. digoxin) (generally essential, but arguably should not form part of drug dosage calculation education).
- Knowledge regarding the medication administered; specifically use and dosage range (essential, but a separate skill from dosage calculation).
- Memorise conversions (generally optional / not important).

This information forms a general framework which itemises mathematical concepts actually identified between 1982 and 1998, or perceived as important in the solving of medication dosage calculation problems. These elements of dosage calculations were used to supplement both my own and my colleagues professional knowledge of dosage calculations performed in clinical practice.

Appendix Iiii

Evolution of the Project 2000 Curriculum

Traditional versus Project 2000 Curricula

To appreciate the problems encountered by students when learning medication dosage calculation skills, it is essential to recognise the structure of the programme within which the skills are developed. An historical perspective of the evolution of the current nurse education programme serves as a backdrop to this aim.

Prior to the wholesale movement of nurse education into higher education establishments, student nurses had previously followed traditional pre-registration nurse preparation programmes, that were based on an apprenticeship model of training. This took the form of an initial six to twelve week school-based introduction to 'nursing' and relevant 'fundamental anatomy and physiology etc.'. This was followed by alternating periods of clinical practice interspersed with school-based study blocks. Students were taught in the classroom by 'nurse tutors', who were registered nurses with a relevant teaching qualification; and by doctors and clinical nurses who were 'brought in' to teach their 'specialities'. Thus formal teaching provided background information which centred particularly upon medically oriented facts about disease and its treatment (Bond and Bond 1986). However in terms of matching theory with experience a key problem of the traditional curriculum was that the theory content of study blocks was often unrelated to the subsequent clinical placement. That is as the theory content was 'disease oriented', a study block that was centered on traumatic injuries and orthopaedics, could not possibly be followed by the whole cohort of students being allocated to trauma and orthopaedic clinical settings - there were just not enough available clinical areas.

During periods of clinical nursing practice students followed an apprenticeship style model. This involved 'on the job' training, during which clinical nurse teachers provided occasional clinical teaching sessions, and registered nurses, or more commonly senior student nurses and unofficially nursing auxiliaries acted as 'role models' to the more junior student. The nursing student progressing through a socialisation and *rites de passage* process, involving a gradual increase in both allocated responsibility and status as he/she progressed throughout the 3-year training.

However in her doctoral thesis Melia (1981) highlighted a range of problems with this process of learning. That is the combined effect of student nurses being treated as 'pairs of hands', and of working rather more often with other students and nursing auxiliaries than with registered nurses, conspired to produce a deficient education process. Melia pointing out that to label the training of nurses as that of an apprenticeship model was derogatory to the concept, as apprentices were aligned with 'craftsmen' and not 'labourers'. In essence the effective paucity of contact with registered nurses, meant that while students developed skills and proficiency in performing clinical tasks, they failed to develop a relevant 'model of nursing', or to be prepared for the professional role of the staff nurse (Bond and Bond 1986). The assessment of clinical competence tended to be measured by 'ward reports' completed by registered nurses (who had rarely worked with the student); and 'one off' snapshot assessments of such skills as wound dressings and aseptic technique, administration of medicines and ward management etc. The sequencing of clinical assessments was usually predetermined and hence students were allowed a series of 'trial runs' at performing the relevant skill in the period immediately preceding the assessment. Thus the learning of medication dosage calculation skills was commonly restricted to the isolated periods preceding relevant clinical assessments, and to periods when students could be 'spared' to accompany registered nurses during the 'drug round'. Moreover the opportunities for linking relevant dosage calculation formulae (if and when the *theory* was taught in schools of nursing) with the *experience* of performing the skill in clinical practice, was at best highly variable. Ultimately this together with the often mis-match of study block theory and subsequent clinical experience led to the creation of a theory-practice divide.

In 1986 the United Kingdom Central Council for Nursing, Midwifery & Health Visiting (UKCC) proposed a new approach to the pre-registration preparation of nurses. In their discussion document titled *Project 2000: A new preparation for practice*, the UKCC outlined their vision of an education strategy that responded to the weaknesses of the traditional programme, while preparing practitioners to function within, and respond to an ever changing world. The notion of the 'knowledgeable doer' was proposed, and in 1989 the Welsh Office published a position paper highlighting five key changes to the future pre-registration preparation of nurses:

I. Training was to be divided into two periods. A common foundation programme (CFP) of 18 months and a further 18 months to specialise in one of 4 branches: child, adult, mental health or learning disability.

II. Nurse learners were to have student status with a bursary being granted.

III. Nurse education was to be linked with Higher Education, rather than with Health Authorities.

IV. During clinical placements student time on rotas would be reduced, but training would be kept both practical and patient oriented.

V. There would be one level of qualified nurse only, with a wide entry gate for support worker grade via the Care Sector Consortium.

(Welsh Office 1989, para 4)

The common foundation programme was to incorporate four distinct features:

1. It was to be embedded in health and not illness, and was to have a solid underpinning of relevant bio-psycho-social and professional nursing theory
2. It was to be an integrated theory and practice programme
3. It was to expose the student to a range of settings and to a variety of client groups
4. It was to prepare the student for further learning in the branch programmes

Following successful development of the key fundamental skills that formed the basis of professional nursing practice, the student would progress to one of the four client-related branches. The notion of the 'knowledgeable doer' implicitly highlighting the need to develop a knowledgeable, skilful and flexible practitioner who could respond to an ever changing and evolving world. Within this remit supernumerary status in clinical practice would afford wide opportunities for learners to 'work alongside' registered nurse role models. A basic premise underpinning the programme was that registration protects the public by indicating that the practitioner is safe and competent to practise (UKCC 1986, p. 47). Ultimately individual education establishments and their respective National Board's for Nursing, Midwifery and Health Visitor Education had a statutory responsibility to ensure that courses of training met the requirements of the UKCC, in respect of their kind, content and standard. Thus each individual college developed its own curriculum to reflect both the ethos of the proposed UKCC strategy, and the relevant outcomes demanded by Rule 18 (A) (Statutory Instrument 1989).

Therefore in common with nurse education programmes in England and Scotland, the early 1990s saw the movement of nurse education in Wales, UK, into higher education establishments. At the study site approximately 35 and 220 students respectively were recruited annually onto the pre-registration, 4-year Bachelor of Nursing and 3-year Diploma in Nursing Studies programmes. The remainder of this section outlines the construct of the latter of these two programmes.

The Common Foundation Programme (CFP)

The college developed a CFP consisting of an initial 26 week predominantly college-based programme that centered on fundamental theoretical principles, followed by a 52 week clinical programme interspersed by weekly college-based study days. During the first 26 weeks students were exposed to the principles of key bio-psycho-social factors necessary to achieve and maintain physical and psycho-social well being of the individual. This was integrated within a framework of professional nursing studies, and coupled with the study of a geographical neighborhood within one of the three counties surrounding the college. During week 13 of the CFP, students submitted their first assessed piece of academic work, this taking the form of a Health Based Assignment, centered upon the principles of health and applied to the population of their allocated neighborhood. Following completion of this assignment students were introduced to the concept of altered patterns of bio-psycho-social function, and to the fundamentals of relevant nursing assessments and interventions, utilised to assist clients to meet their health needs. This was in preparation for their first ventures into clinical practice. The clinical element of the CFP consisted of 4 Theory to Practice Units (TPU), and 5 Clinical Placement Units (CPU).

The Theory to Practice Units (TPUs)

As the title suggests the Theory to Practice Units formed the period when theory was initially applied to practice. Each unit extended over a 4-week period and incorporated 4-clinical days and 1-college based study day per week. Each cohort of students was divided into 4 sub-groups, each group being sequentially rotated through all 4 of the TPUs during a 16 week period. The relevant placements were underscored by specific clinical objectives, designed to promote linkage of theory with key features of the clinical experience. The TPU titles were

a) Caring and Therapeutic Intervention (CTI) placement: These were branch specific placements focused upon child, adult and mental health hospital based settings. Students were allocated to settings specific to their chosen branch (the college did not operate a learning disability branch). Key objectives of this TPU centered upon the development of an appreciation of the nursing process, of a multi-disciplinary team approach to health care, and the acquisition of fundamental practical nursing skills (including medication administration). During this placement students in groups of four were accompanied into the clinical areas by college lecturers. This practice was for the purpose of assisting students to bridge the divide between college theory and clinical practice. Additionally as the emphasis was upon direct patient care it gave lecturers opportunities, on two 4-week periods per year, to update their clinical skills in their area of expertise.

b) Primary Health placement: These placements were focused within primary health care teams located in the community. Key objectives centered upon an appreciation of the role of the community based teams, and the acquisition of key assessment, implementation and support skills used in the community setting (including medication administration in GP surgeries, health centers and patients homes).

c) Loss placement: These placements were focused in hospital settings providing experience of the full range of loss. That is from loss of personal identity to altered body image and bereavement associated with death. Key objectives centered upon identification with the various elements of loss, and with the multi disciplinary approach to loss and bereavement (this commonly involved medication administration of analgesia etc.).

d) Community Profiling placement: These placements were focused on specific organizations within the community that contributed to the health and well being of community residents, e.g., the police, community health council etc.. Key objectives centered upon linking the role of these organizations within a health promotion and education framework, together with their policies regarding meeting 'Local' and 'All Wales Health Gain Targets'. As this TPU was split evenly between college and clinical placements, it incorporated the introduction to the Solving of

Medication Dosage Problems unit and the initial college-based written dosage calculation assessment. This will be fully described and explored in Sections 1.7 and 1.8.

The Clinical Placement Units (CPUs)

Following completion of the TPUs, students entered the final part of the Common Foundation Programme. This involved the rotation of students through five 4-week Clinical Placement Units (CPUs), and provided all students with a common foundation in the principles of meeting the requisite needs of :

1. Pregnant women and their family: This unit explored the needs of women and their families during the ante-, peri-, and post-natal periods.
2. Children in a school setting: This unit explored the developmental needs of children in a primary or junior school setting.
3. Adults experiencing a physical or physiological problem: This unit was hospital based and explored the needs of clients in integrated-medicine (medical and care of the elderly), and surgical (general surgery or surgical specialty) health care settings.
4. Adults experiencing a mental health problem: This unit was based in day centre, acute and longer stay mental health care settings.
5. Children, adolescents and adults experiencing a learning disability: This unit was based in schools and community based settings which assisted clients with a learning disability to meet and optimize their education and life potential.

With the exception of the child CPU all these placements included specific objectives centered on administration of medicines to the relevant client group involved.

Assessment in the Common Foundation Programme

Completion of the CFP and progression to the Branch programmes was dependent upon the successful performance in a range of academic assignments and examinations, and clinically-based competencies. The written medication dosage calculation assessment could be attempted on a maximum of three occasions during the CFP. Failure to pass the assessment in the CFP was not a bar to entering the branch programmes. However students were expected to demonstrate competence in this skill by the point of registration. The problems encountered during this process will be analysed and discussed in Section 1.8.

The branch programmes

Following successful completion of the CFP students progressed to one of three branch programmes. All of the clinical placements within the branch programmes continued to include specific objectives related to the safe administration of medications relevant to that client group. That is community, acute, long stay and high-dependency or critical care clinical settings.

Appendix Iiv

Medication Dosage Calculation Assessments undertaken during the CFP

Appendix IA

Medication Dosage Calculation Assessments undertaken during the CFP

Medication Dosage Calculation Assessment - (Phase 1)

Name: ______________________________________

Group: X Y (please circle as appropriate)

Instructions:

- This assessment consists of 3 sections:

1. Conversions of S.I. units
2. Calculation of tablet & capsule, liquid medicine, and injection dosages
3. Calculation of infusion volume and drop rates

- Each section consists of 10 questions
- Please attempt all questions (recall that you require 100% in each section to fulfil the college requirements)
- Calculators are *not permitted*
- Enter your answers in the *answer boxes* provided
- Please write all your *calculations* and *workings* in the boxes provided
- DON'T PANIC

Good Luck,

Keith W. Weeks (Lecturer)

Plese turn over the page and begin

Section 1 - Conversions of S.I. Units

1. Convert:

1 litre (L) to millilitres (ml):

Please show any calculations / workings here	Answer

2. Convert:

250 millilitres (ml) to litres (L):

Please show any calculations / workings here	Answer

3. Convert:

0.5 gram (g) to milligrams (mg):

Please show any calculations / workings here	Answer

4. Convert:

0.1 gram (g) to milligrams (mg):

Please show any calculations / workings here	Answer

5. Convert:

1000 milligrams (mg) to grams (g) :

Please show any calculations / workings here	Answer

Section 1 - Conversions of S.I. Units (continued)

6. Convert:

250 milligrams (mg) to grams (g):

Please show any calculations / workings here	Answer

7. Convert:

1 milligram (mg) to micrograms (mcg):

Please show any calculations / workings here	Answer

8. Convert:

0.0625 milligram (mg) to micrograms (mcg):

Please show any calculations / workings here	Answer

9. Convert:

125 micrograms (mcg) to milligrams (mg):

Please show any calculations / workings here	Answer

10. Convert:

500 micrograms (mcg) to milligrams (mg) :

Please show any calculations / workings here	Answer

Section 2 - Tablet & Capsule Dosages

Question 1:

Drug Name:	Prescribed Dose:	Dispensed Dose:	Contained in:	How many Tablets/Capsules
Cimetidine	400 mg	400 mg	1 tablet	Answer

Please show your calculations / workings here:

Question 2:

Drug Name:	Prescribed Dose:	Dispensed Dose:	Contained in:	How many Tablets/Capsules
Flupenthixol	9 mg	3 mg	1 tablet	Answer

Please show your calculations / workings here:

Question 3:

Drug Name:	Prescribed Dose:	Dispensed Dose:	Contained in:	How many Tablets/Capsules
Captopril	12.5 mg	25 mg	1 tablet	Answer

Please show your calculations / workings here:

Section 2 - Liquid Medicine Dosages

Question 4:

Drug Name:	Prescribed Dose:	Dispensed Dose:	Contained in:	How many ml
Amoxycillin oral suspension	125 mg	125 mg	5 ml	Answer

Please show your calculations / workings here:

Question 5:

Drug Name:	Prescribed Dose:	Dispensed Dose:	Contained in:	How many ml
Chlorpheniramine Maleate	1 mg	2 mg	5 ml	Answer

Please show your calculations / workings here:

Question 6:

Drug Name:	Prescribed Dose:	Dispensed Dose:	Contained in:	How many ml
Codeine Phosphate Syrup	30 mg	25 mg	5 ml	Answer

Please show your calculations / workings here:

Section 2 - Injection Dosages

Question 7:

Drug Name:	Prescribed Dose:	Dispensed Dose:	Contained in:	How many ml
Metoclopramide injection	10 mg	10 mg	2 ml ampoule	Answer

Please show your calculations / workings here:

Question 8:

Drug Name:	Prescribed Dose:	Dispensed Dose:	Contained in:	How many ml
Haloperidol Decanoate injection	25 mg	50 mg	1 ml ampoule	Answer

Please show your calculations / workings here:

Question 9:

Drug Name:	Prescribed Dose:	Dispensed Dose:	Contained in:	How many ml
Morphine Sulphate	2.5 mg	10 mg	1 ml ampoule	Answer

Please show your calculations / workings here:

Section 2 - Injection Dosages

Question 10:

Drug Name:	Prescribed Dose:	Dispensed Dose:	Contained in:	How many ml
Actrapid Insulin injection	20 units	100 units	1 ml	Answer

Please show your calculations / workings here:

Section 3 -I.V. Infusion Volumes & Drop Rates

Question 1:

I.V. Fluid Name:	Prescribed Volume:	Infusion Time:	Number of drops/ml delivered by administration set:
Sodium Chloride 0.9%	1000 ml	8 hours	20 drops / ml

a. How many millilitres per hour **Answer**

Please show your calculations/workings here	

b. How many drops per minute **Answer**

Please show your calculations/workings here	

Question 2:

I.V. Fluid Name:	Prescribed Volume:	Infusion Time:	Number of drops/ml delivered by administration set:
Glucose 5%	1000 ml	12 hours	20 drops / ml

a. How many millilitres per hour **Answer**

Please show your calculations/workings here	

b. How many drops per minute **Answer**

Please show your calculations/workings here	

Section 3 -I.V. Infusion Volumes & Drop Rates

Question 3:

I.V. Fluid Name:	Prescribed Volume:	Infusion Time:	Number of drops/ml delivered by administration set:
Glucose 5%	250 ml	5 hours	60 drops / ml

a. How many millilitres per hour **Answer**

Please show your calculations/workings here

b. How many drops per minute **Answer**

Please show your calculations/workings here

Question 4:

I.V. Fluid Name:	Prescribed Volume:	Infusion Time:	Number of drops/ml delivered by administration set:
Whole Blood	450 ml	6 hours	15 drops / ml

a. How many millilitres per hour **Answer**

Please show your calculations/workings here

b. How many drops per minute **Answer**

Please show your calculations/workings here

Section 3 -I.V. Infusion Volumes & Drop Rates

Question 5:

I.V. Fluid Name:	Prescribed Volume:	Infusion Time:	Number of drops/ml delivered by administration set:
Packed Red Blood Cells	280 ml	4 hours	15 drops / ml

a. How many millilitres per hour **Answer**

Please show your calculations/workings here	

b. How many drops per minute **Answer**

Please show your calculations/workings here	

Thank you for completing this assessment

Before returning this answer sheet to the supervising lecturer please ensure that you have:

1. **Completed the details requested on the front page**
2. **Attempted all 10 questions in all 3 sections**
3. **Checked your answers for accuracy**

Appendix II

Appendix II

Written instructions provided to lecturers for implementation of the TCSM

Test of Cognitive Style in Mathematics
(Adapted from Bath, Chinn and Knox 1986)

Introduction

The TCSM has been devised to assess individual's cognitive style in mathematics. The terms **'inchworm'** and **'grasshopper'** have been coined to describe two extreme styles or approaches to solving mathematics problems. The classifications appear at the extreme ends of a continuum, with an **'intermediate'** style incorporating elements of both styles lying between the polar ends. The terms 'inchworm' and 'grasshopper' focus upon **observable behaviours** rather than unseen neurological causation's. Hence the test is of pragmatic use to the student and educator in respect of identifying each individuals preferred **computation** and **problem solving** methods. This provides a more complete understanding of the individuals learning preferences and facilitates: student self awareness, the potential for matching teaching strategies with relevant style, and a potential increase in flexibility via instruction in strategies of the opposing style.

The test consists of **15 mathematics questions** in **3 subsets** (the algebra section has been omitted):

- **Mental computation**: This examines the four operations with whole numbers, i.e., *addition, subtraction, multiplication division.* Emphasis is upon mental mathematical strategies and **paper and pencil are <u>not permitted</u>** for this section, but may be used for the ensuing two sections.
- **Arithmetic**: This examines *whole number addition, decimal multiplication, digit series, number pattern analysis, and arithmetic average.*
- **Geometry / Visual:** This examines *pattern analysis, area, geometric progression, multi-pattern analysis and volume.*

General instructions for administering the TCSM

Physical Setting:
Test conditions can make significant differences in the subject's performance. The physical setting should be free from distractions and noise, with adequate lighting, and a table and two chairs. It is recommended that the student and examiner sit across from each other or at right angles with the table between them.

Rapport:
The TCSM has been designed to cause as little anxiety as possible. Correct answers are not crucially important, as the *method* of computation or problem solving is more important. A *relaxed atmosphere* should be established for testing each student. If a student has difficulty solving a problem, then he/she should be asked after encouragement, to explain how the problem could be solved. **Be especially careful not to lead the subject.**

Administration time:
The TCSM is *untimed*, that is it is a *power and not a speed test.* For most students the administration time is approximately 15 minutes. However this may vary from 10 minutes (for grasshoppers), to 30 minutes (for inchworms).

Specific instructions for administering the test

Materials:

- TCSM Worksheet
- Observation Folder & Record Sheet
- Profile Record

Method:

The organisation of the assessment and the statements below are those suggested by Bath, Chinn and Knox (1986). It is not essential that these statements are spoken verbatim, however the general organisation of the assessment presentation should be adhered to.

a) Say 'here is a worksheet. Complete the heading and then read the instructions with me'. Take the pencil off the student.

b) Say 'I am going to ask you five problems that you can solve in your head. You may *not* use paper and pencil for this part of the test. Remember, I am interested in the *method* you use. Your answer is less important to me than your method. If you cannot obtain a final answer, just tell me the method you are trying to use'. Reveal individual questions one at a time. The answers and relevant strategies/scores for each question are included in the observation folder. Complete the mental computation section of the test and record your observations of the strategy used by the student in the Observation Folder.

c) Return the pencil to the student. Say 'You may now use the pencil and paper at any time from now on.

d) Read each problem one at a time. Record your observations in the relevant section of the Observation Folder.

e) A student is allowed to miss one question (not able to answer or provide a method for solving the problem), from each section before that section becomes invalid.

f) Total each individual section scores and transfer the scores to the Profile Record. This will facilitate classification of the student as demonstrating an inchworm, intermediate or grasshopper style.

g) Inform the student that once the scores have been finalised and collated that they will be informed of their relevant learning style in mathematics; and that they will have an opportunity to discuss the outcome. Reassure the student that the TCSM is designed to assist them to understand their relevant learning style; and to assist the college lecturing staff to develop teaching strategies that assist students to learn the numerical concepts required to practice as a registered nurse.

Inchworm and Grasshopper Strategies

Inchworm:
The inchworm will use small sequential steps and is likely to use pencil and paper. The main focus of his/her approach is to find a suitable formula or recipe. He/she is unlikely to round off numbers to form an estimate or answer, nor check his/her final answer.

Grasshopper:
The grasshopper will resist use of pencil and paper. He/she may form initial estimates of an answer, restrict the range of possible answers, and / or try several methods concurrently. The strategies used are likely to focus on holistic concepts and the parts.

Intermediate:
Individuals classified as intermediate demonstrate manifestations of both styles.

Scoring method

The inchworm - intermediate - grasshopper scoring method is ranged along a continuum:

15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45

Inchworm

Intermediate

Grasshopper

Inchworm strategies score: **1**
Intermediate strategies score: **2**
Grasshopper strategies score: **3**

Following removal of the algebra section, the TCSM contains 15 questions. Therefore the *extreme inchworm* would score 15 x 1 = 15 points on the TCSM. The *extreme grasshopper* would score 15 x 3 = 45 on the TCSM. The *pure intermediate* would score 15 x 2 = 30 on the TCSM. However there will clearly be a variation on this theme.

Instruction methods appropriate to learning style

Although not a component of the administration method for the TCSM, students may request information regarding their particular style. I will discuss this with all the participants on completion of the research study. However if you wish to provide general information regarding instruction methods appropriate to the 'inchworm' and 'grasshopper' styles, the points below may prove useful:

Inchworms (low scores): Tend to use formulae and favour formulae that remain consistent throughout the programme. Subsequently the inchworm will need help in evaluating and understanding problems. Typically he/she will launch into a formula or algorithm without overviewing the problem or considering possible values for an answer. The inchworm needs to develop estimation and review skills in order to be answer-oriented as well as process-oriented.

Grasshoppers (high scores): Tend to prefer to 'see the whole problem' and see the concrete features relevant to the problem. The grasshopper will need help and encouragement in using formulas. He/she tends to work mentally and quickly, but his/her strategies will not solve all problems. For example, a grasshopper can quickly and accurately solve percentages which relate to 10%. Thus 30% (3 x 10%) and 15% (10% + $\frac{1}{2}$ x 10%) are quickly computed. However he/she will need help and encouragement with values such as 13.6% and 37% etc..

Appendix III

Appendix III

TCSM worksheet illustrating the problems to be solved in the three subtests

Mental Computation (MC)

1. 220 + 98 =
2. 220 - 98 =
3. How much is 25 x 96 =
4. How much is 2 x 4 x 3 x 5 =
5. How much is 95 divided by 5 =

Arithmetic

Question 1: What is the sum of these numbers?

1 + 2 +3 + 4 + 5 + 6 + 7 + 8 + 9 =

Question 2: What is the product of:

80 x 1.5 =

Question 3: These are the first six numbers of a series. What is the 23rd number in this series?

1, 2, 3, 1, 2, 3,.................

Question 4: This is a calendar showing the month of May. It has been written backwards. If it continues to go backwards what day of the week will be May 1st?

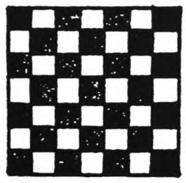
SUN	MON	TUES	WED	THUR	FRI	SAT
				31	30	29
28	27	26	25	24	23	22
21	20	19	18	17	16	15

Question 5: What is the arithmetic average of these test scores?

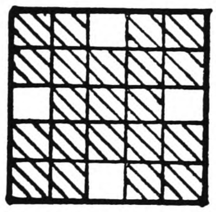
80, 85, 90, 95, 100

Geometry / Visual

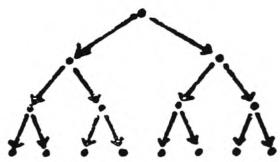
Question 1: How many black squares are in the diagram below:



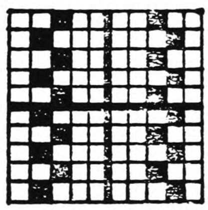
Question 2:How many little squares are shaded in the diagram below:



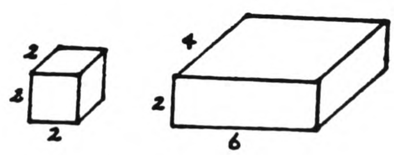
Question 3: Each dot divides. If they continue to divide in this way, how many dots would be in row 6?



Question 4: What fraction of the entire figure is shaded in the diagram below?



Question 5: How many cubes 2-inches on an edge will fit into the box?



Appendix IV

Appendix IV

Adapted Observation Folder and Record Chart

Mental Computation (MC)	Appropriate Observation		Score
<u>Say</u>: calculate the answer in your head; you may <u>not</u> use paper & pencil	IW = (inchworm) Inter = (intermediate) GH = (grasshopper)		= 1 = 2 = 3
MC-1 **Ask: how much is** **220 + 98** **Ask: how did you do it?** **Answer: 318** correct/incorrect	☐ added as with pencil & paper ☐ 220 + 80 + 18 ☐ 220 + 100 - 2 ☐ 220 - 2 + 100 ☐ other	(IW) (Inter) (GH) (GH)	1 2 3 3
MC-2 **Ask: how much is** **220 - 98** **Ask: how did you do it?** **Answer: 122** correct/incorrect	☐ subtracted as with pencil & paper ☐ 100 - 98 + 120 ☐ 220 - 100 + 2 ☐ 220 + 2 - 100 ☐ other	(IW) (Inter) (GH) (GH)	1 2 3 3
MC-3 **Ask: how much is** **25 x 96** **Ask: how did you do it?** **Answer: 2400** correct / incorrect	☐ multiplies as with pencil and paper ☐ (10 x 96) + (10 x 96) + (5 x 96) ☐ (25 x 100) - (25 x 4) ☐ (96 / 4) x 100 ☐ other	(IW) (Inter) (GH) (GH)	1 2 3 3
MC-4 **Ask: how much is** **2 x 4 x 3 x 5** **Ask: how did you do it?** **Answer: 120** correct/ incorrect	☐ multiplied in order ☐ 8 x 15; (2 x 4) x (3 x 5) ☐ 12 x 10; (4 x 3) x (2 x 5) ☐ 6 x 20; (2 x 3) x (4 x 5) ☐ other	(IW) (Inter) (GH) (GH)	1 2 3 3
MC-5 **Ask: how much is** **95 divided by 5** **Ask: how did you do it** **Answer: 19** correct incorrect	☐ divided as with pencil and paper ☐ (50 / 5) + (45 / 5) ☐ (55 / 5) + (40 / 5) ☐ 100 / 5 = 20, then 1 less ☐ other	(IW) (Inter) (Inter) (GH)	1 2 2 3
Total Correct = /5		**Total Score =**	

Arithmetic (AR) <u>Say</u>: please use this worksheet: you may use use paper & pencil	Appropriate Observation IW = (inchworm) Inter = (intermediate) GH = (grasshopper)		Score = 1 = 2 = 3
AR-1 **Ask: what is the sum of the numerals 1 to 9** **Ask: how did you do it?** **Answer: 45** correct/incorrect	☐ adds in order ☐ grouping scheme other than 10 e.g.: (1 + 2) + (3 + 4) + ...(8 + 9) = ☐ groups of 10 i.e.: (1 + 9) + (2 + 8) + (3 + 7) etc. ☐ other	(IW) (Inter) (GH)	1 2 3
AR-2 **Ask: what is the product of 80 x 1.5** **Ask: how did you do it?** **Answer: 120** correct/incorrect	☐ 80 x <u>1.5</u> *(traditional algorithm)* 400 *(counting to place the* <u>800</u> *decimal)* <u>120</u> ☐ 15 x <u>8</u> *(the decimal is removed)* <u>120</u> ☐ 80 *(sees 1.5 as 1 & 1/2 of 80)* + <u>40</u> <u>120</u> *(adds 80 + 40)* ☐ other	(IW) (Inter) (GH)	1 2 3
AR-3 **Say: these are the first 6 numbers in a series. What is 23rd number in the series?** **Ask: how did you do it?** **Answer: 2** correct/ incorrect	☐ rewrites the six digits and continues to 23rd digit ☐ writes and counts along a series of 23 dots ☐ groups in 3's *(sees the series as a repeating pattern of 3, i.e., 23rd digit is two more than 4 x 6)* ☐ groups in 6's *(sees the series as a repeating pattern of 6, i.e., 23rd digit is one less than 4 x 6)* ☐ other	(IW) (IW) (GH) (GH)	1 2 3 3

Arithmetic (AR) **<u>Say</u>: please use this worksheet: you may use use paper & pencil**	**Appropriate Observation** **IW = (inchworm)** **Inter = (intermediate)** **GH = (grasshopper)**	**Score** **= 1** **= 2** **= 3**
AR-4 **Say: this is the month of May. It has been written backwards. If it continues to go backwards what day Of the week will be May 1st** **Ask: how did you do it?** **Answer: Saturday** correct/incorrect	☐ counts backwards to 1 (IW) *(points to the days until day 1 is reached)* ☐ e.g., subtracts 17 - 7 = 10 then 10 - 7 = 3, and finally (Inter) ☐ 15, 8, 1 (Saturday) (GH) ☐ 15 - 14 = 1 (Saturday) (GH) *(looks at the pattern of numbers for Saturday and swiftly subtracts sevens, i.e., 29, 22, 15, 8, 1* ☐ other	1 2 3 3
AR-5 **Ask: what is the arithmetic average of these test scores 80, 85, 90, 95, 100** **Ask: how did you do it?** **Answer: 90** correct/incorrect	☐ adds then divides by 5 (IW) $\overline{90}$ 5/ 450 *(the numbers are added probably in column form, and then divided by 5. The extreme inchworm is likely to write down the division as above)* ☐ answers 90 with no written computation (GH) *(surveys the group of numbers and sees a balance about the number 90, i.e., the number 80 is 10 below 90, while the number 100 is 10 above; the number 85 is 5 below 90, while 95 is 5 above.* ☐ other	1 3
Total Correct = /5		**Total Score =**

Geometry/visual (G/V) **<u>Say</u>: please use this worksheet: you may use use paper & pencil**	**Appropriate Observation** **IW = (inchworm)** **Inter = (intermediate)** **GH = (grasshopper)**		**Score** **= 1** **= 2** **= 3**
GV-1 **Ask: how many black squares are there in the diagram below** **Ask: how did you do it?**	☐ counts squares *(since there are not equal numbers of black & white squares, the inchworm will probably resort to counting squares)*	(IW)	1
Answer: 25 correct/incorrect	☐ adds 4 + 3 + 4 +3 + 4 + 3 + 4	(Inter)	2
	☐ adds: 16 + 9 *(it is possible to see a pattern of black squares in each line as alternative 4's and 3's. Thus the answer is achieved by 4 + 3 + 4 + 3 etc., or sees a pattern of 4 rows of 4 (16) and 3 rows of 3 (9).*	(Inter)	2
	☐ 1/2 of 49 = $24\frac{1}{2}$ *(the calculation is swift and holistically analytic. The 7 x 7 squares are divided by 2 and taken to 25, since observation of corners indicate more black squares).*	(GH)	3
	☐ other		
G/V-2 **Ask: how many little squares are shaded?** **Ask: how did you do it?** **Answer: 21** correct/incorrect	☐ counts squares	(IW)	1
	☐ adds 5 + 5 + 3 + 5 + 4	(Inter)	2
	☐ adds (4 x 4) + 5 *(the pattern can be seen as four 2 x 2 squares in each corner, separated by a cross of 5 squares. The number of squares in the cross is frequently miscounted as 4 or 6)*	(Inter)	2
	subtracts 25 - 4 *(the grasshopper sees the pattern as a 5 x 5 square with four parts missing, and thus 25 - 4 = 21 squares)*	(GH)	3
	☐ other		

Geometry/Visual (GV) **Say**: **please use this worksheet: you may use use paper & pencil**	**Appropriate Observation** **IW = (inchworm)** **Inter = (intermediate)** **GH = (grasshopper)**		**Score** **= 1** **= 2** **= 3**
G/V-3 **Say: each dot divides. If they continue to divide in this way, how many dots would be in row 6** **Ask: how did you do it?** **Answer: 32** correct/incorrect	☐ draws and counts	(IW)	1
	☐ any form of counting total	(IW)	1
	☐ counting part, then multiplies *(the pattern may not be discerned until it has been partly redrawn. The student may draw one quarter of dots multiply the answer by four)*	(Inter)	2
	☐ pattern 2, 4, 8, 16, 32	(GH)	3
	☐ multiplies by 2 twice *(the grasshopper will view the complete pattern and see the geometric progression as a pattern of doubling 2, 4, 8, 16, 32*	(GH)	3
	☐ other		
G/V-4 **Ask: what fraction of the entire figure is shaded** **Ask: how did you do it?** **Answer: 1/5** correct/incorrect	☐ counts 20; 20/100 = 1/5 *(the black squares are counted individually. The total number of squares will probably be calculated and then the fraction will be calculated from 20/100 before arriving at 1/5)*	(IW)	1
	☐ uses quarter section 5/25 or 1/5	(Inter)	2
	☐ 4 x 5 = 20, 20/100 or 1/5 *(the student sees that the pattern is made up of four quarters, and analyses one quarter as 5/25. Concludes the whole is also 1/5)*	(Inter)	2
	☐ 2 complete columns 2/10 or 1/5 *(by sliding the blank squares in one quarter together, to make one black line out of five, the grasshopper quickly sees that the whole pattern is made up by 1/5 black squares).*	(GH)	3
	☐ other		

Geometry/Visual (GV) **<u>Say</u>: please use this worksheet: you may use use paper & pencil**	**Appropriate Observation** **IW = (inchworm)** **Inter = (intermediate)** **GH = (grasshopper)**		**Score** **= 1** **= 2** **= 3**
G/V-5 **Ask: how many cubes 2-inches on edge will fit into the box?** **Ask: how did you do it?** **Answer: 6** correct/incorrect	☐ draws in cubes	(IW)	1
	☐ 2 x 4 x 6 = 48; 48/8 = 6 *(the inchworm way either draw in the cubes, or will calculate the volume of the large cuboid and the small cube. The number of cubes which will fill the cuboid is calculated by division. This question can also illustrate the inchworm's reluctance to pre-estimate an answer or check the solution. A common error is to calculate the volume of the small cube as 4, resulting in a final answer of 12).*	(IW)	1
	☐ 2 x 3 = 6	(GH)	3
	☐ 'sees' 6 *(the grasshopper looks at the two volumes and decides that three cubes can fit along one side and two along the other. Thus the answer is two rows of three).*	(GH)	3
	☐ other		
Total Correct = /5		**Total Score =**	

Appendix V

Appendix V

Adapted version of the Profile Record

Test of Cognitive Style in Mathematics
(Adapted from Bath, Chinn and Knox 1986)

Student's Name: ____________________________________

Scoring

A score of **1, 2** or **3** is given to each method or strategy according to the cognitive style it represents:

Inchworm strategies score: **1**
Intermediate strategies score: **2**
Grasshopper strategies score: **3**

Profile Record

Score Total Mental Computation		Score Total Arithmetic		Score Total Geometry/Visual		Total Score
	+		+		=	

Analysis of Total Score

15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45

15 **Inchworm** 24		
	25 **Intermediate** 35	
		36 **Grasshopper** 45

Cognitive Style in Mathematics Classification

Please ✓ the appropriate classification:

Inchworm ☐

Intermediate ☐

Grasshopper ☐

Appendix VI

Research Information Details Provided to Participants

Medication Dosage Calculation Research

Intake details omitted for confidentiality purposes

Dear

Thank you for consenting to participate in the *Medication Dosage Calculation Research Project*, being undertaken at the School of Nursing Studies (SONS). The intention of this information pack is to formally outline the key details and design of the project; together with the essential details of your role within the project.

Key researcher: Keith W. Weeks

Research rationale: The project forms part of ongoing data collection within the SONS; regarding relevant teaching/learning strategies and medication dosage calculation skill development among nursing students. More formally the data generated and collected within this project will form part of a Ph.D. thesis being undertake by the key researcher.

Ethical considerations: The project has been granted full ethical approval by the Dean of Nursing Studies.

Confidentiality considerations: Neither the college or any student participating in the project will be cited by name in the Ph.D. thesis or any publication associated with this project.

Key Stages of the Project

1. Random selection and allocation of volunteer participants to two groups (X and Y)

2. Assessment of participants Cognitive Style in Mathematics (November 98 to January 99)

3. Phase 1 of Data Collection and Assessment (February 99)

4. Phase 2 of Data Collection and Assessment (March 99)

5. Phase 3 of Data Collection and Assessment (April - July 99)

Stage 1

Random Selection of Volunteer Participants to Groups X and Y

The following 44 students have been randomly allocated to the two groups below. Please note carefully the group you have been allocated to, and the relevant dates and times of timetabled research sessions. These are clearly outlined in the accompanying information pack.

Please note these dates and times in your diary NOW

Names omitted for confidentiality purposes

Stage 2

This stage involves the assessment of your *Cognitive Style in Mathematics (CSM)*.

An assessment tool has been devised by Bath, Chinn and Knox (1986) to identify individuals cognitive learning style in mathematics. This assessment is of use to both education staff and you as a nursing student in respect of:

- Identifying your preferred computation and problem solving methods

- The potential for assessing the usefulness of teaching strategies against your relevant style

The assessment consists of 15 questions in 3 subsets:

- Mental computation
- Arithmetic
- Visual patterns

The assessment has no time limit (however it will probably take you between 15 and 20 minutes to complete).

The key intention of the assessment is to identify the *approach you use to work out the problems*. Therefore this of much greater importance than whether you get the correct answer.

For the purposes of the assessment you have been allocated to an individual college lecturer who will conduct the confidential assessment. It is important to undertake the CSM assessment prior to commencement of stages 3 & 4 of the project; (i.e., between 30 November 1998 and 29 January 1999). Therefore would you please contact and negotiate a mutually convenient date and time with your allocated lecturer, to undertake this assessment (see over).

Assessment of Cognitive Style in Mathematics

Student	**Allocated Lecturer**

Names omitted for confidentiality purposes

Stages 3 & 4

General Details

These stages of the project centre upon:

Exposure of the two groups (X & Y) to two varieties of teaching/learning strategies during two distinct phases:

- Phase 1 (4 weeks - February 1999)

Group X: Computer based 'Authentic World' Programme
Group Y: Lesson & Tutorial
30 Point medication dosage calculation assessment

- Phase 2 (4 weeks - March 1999)

Group X: Lesson & Tutorial
Group Y: Computer based 'Authentic World' Programme
30 Point medication dosage calculation assessment

- Phase 3 (March - July 1999)

A sub-sample of 9 participants will be selected for assessment during clinical practice. This will involve a series of assessments of selected participants ability to calculate medication dosages in clinical areas. This *will not involve contact with patients*, and will additionally involve an approximately one hour confidential audio taped post assessment interview. Participants selected for inclusion in this phase of the research will be contacted shortly after completion of Phase 2 of the research - once again *participation is on a purely voluntary basis.*

The detailed timetabled sessions relevant to Phases 1 & 2 are outlined overleaf.

General research questions and rationale:

1. To investigate the relationship between the type and sequencing of the above teaching/learning strategies and the development of medication dosage calculation skills among nursing students.

2. Do the above teaching/learning strategies support the learning of nursing students demonstrating a range of learning styles in mathematics.

Research design and ethical responsibilities of the key researcher:

Ethically it would be inappropriate to undertake the project in the first four months of the programme (i.e., October 98 to January 99 inclusive), as during this period the first piece of academic work (Health Based Assignment) is being prepared and submitted. Additionally Information Technology Skills are taught during this period.

The research project will run in addition to the traditional medication dosage calculation tuition and assessment sessions undertaken during the Theory to Practice Units [TPUs] (April to July inclusive).

Any student participating in the research project, who passes the medication dosage calculation assessment during the course of the project, will be excluded from both the relevant tuition and assessment sessions in the TPUs. During these sessions students who have passed the assessment in its *entirety* will be awarded private study.

The key researcher and the college has a professional obligation to ensure that no student is disadvantaged by participating in the project. Therefore any student who fails to pass the medication dosage calculation assessment in its entirety during the research project, will be permitted a further three attempts during the CFP period.

Key role of students participating in the project:

This is a serious piece of education research which depends upon the integrity of you as a participant. Therefore please note the following key requests:

- As a volunteer it is requested that you attend *all* timetabled research project sessions and assessments (both phase 1 and 2). Note that these sessions are *in addition* to the programme sessions undertaken by the remainder of the intake. During the timetabled research project sessions the remainder of the group will be awarded private study.

- A key element of the project centres upon investigation of the efficacy of the teaching strategy sequencing: i.e., is there any difference in the effectiveness of utilising the computer based 'Authentic World' learning environment first, followed by lesson/tutorial, and vice-versa. Therefore to ensure validity of the project it is requested that members of Group X do not share their resources with members of Group Y and vice-versa during the project.

Please recall that participation in the project is purely voluntary. Therefore it is requested that if you feel that you cannot meet the above commitment that you inform the college immediately, such that other students can be approached to participate in the project.

Timetable - Medication Dosage Calculation Research

Week	Group & Treatment	Group & Treatment
Phase 1 1	**Computer Laboratory** Group X Computer-based 'Authentic World' learning environment (duration 1 hour 30 minutes) *Provided with 30 point practice assessment paper*	**Classroom** Group Y Teacher led lesson incorporating contextualised word problems (duration 1 hour 30 minutes) *Provided with 30 point practice assessment paper*
3	Group X Computer-based 'Authentic World' learning environment (duration 1 hour 30 minutes) *Provided with answers to 30 point practice assessment paper*	Group Y Teacher led tutorial addressing key problems (duration 1 hour 30 minutes) *Provided with answers to 30 point practice assessment paper*
4	**30 point written medication dosage calculation assessment**	
Phase 2 5	**Computer Laboratory** Group Y Computer-based 'Authentic World' learning environment (duration 1 hour 30 minutes) *Provided with 30 point practice assessment paper*	**Classroom** Group X Teacher led lesson incorporating contextualised word problems (duration 1 hour 30 minutes) *Provided with 30 point practice assessment paper*
7	Group Y Computer-based 'Authentic World' learning environment (duration 1 hour 30 minutes) *Provided with answers to 30 point practice assessment paper*	Group X Teacher led tutorial addressing key problems (duration 1 hour 30 minutes) *Provided with answers to 30 point practice assessment paper*
8	**30 point written medication dosage calculation assessment**	

Thank you for your continued co-operation,
Keith W. Weeks (Lecturer)

Appendix VII

Ethical Consent
to
Undertake Research

Dean of Nursing Studies
Professor Bryn D. Davis

28th September 1998

Mr. K. W. Weeks
Lecturer in Nursing,

Dear Keith,

Thank you for letting me see your PhD proposal. This looks a most interesting study, and as we have discussed before, a very topical one.

I am happy to support your project and accept your reassurance about confidentiality and anonymity. You will presumably negotiate access and the involvement of the students with the respective course leaders.

I hope all goes well.

Yours sincerely,

Professor Bryn D. Davis
Dean of Nursing Studies

Appendix VIII

Appendix VIII

Instructions for Use of Medication Dosage Calculation CD-ROM Disc

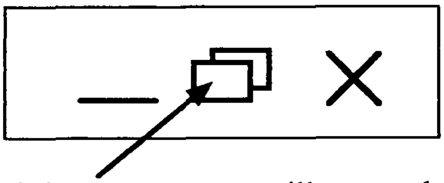
1. You will require Windows 95 or 98, and a good graphics & sound card incorporated into your computer (e.g. the computers situated in the Teaching Lab at the school).

2. Turn on the computer (if you are using the computers within the school, *when prompted to boot to the network:* ***Select No (N)***.) The computer will now boot to 'Windows'.

3. I have incorporated an automatic auto-start facility into the program. Therefore insert the CD-ROM into the CD disc port and it will start automatically.

4. If you are using the computers within the school, please obtain and use a set of *earphones* from the IT Manager. You may need to adjust the sound levels on the computers - other students commonly adjust these inappropriately!

5. The program is designed to fit any size screen. Following initial boot up, a typical Windows interface appears on the screen. In the top right corner appear the screen sizing icons:



Click on the centre *box* icon and the menu page will expand to fill the screen.

Then:

a) Go to Introduction: All buttons in the program are activated with the *left mouse button*. An initial acknowledgement screen appears for 12 seconds, and then automatically rolls on to the Introduction section.

b) Follow the on screen instructions.

c) At the end of each section you will be automatically returned to the menu page and prompted to move on to the next section.

d) At the commencement of each section you will be given 3 options, i.e., to go to the: self-assessment section, the tutorial section; or to quit. Please go to the *self-assessment section* to assess your current level of skills.

e) Should you wish to quit the program at any point when a 'quit' button is not present on the screen: *Press the 'Esc' key at the top left corner of the keyboard.* To close the program down *click 'exit'* on the menu page.

f) Toward the end of the *Conversion of SI units section*, there is a slight loss of synchronisation between the commentary and the graphics. This is a fault of the authoring package used to write the program - please do not attempt to adjust your computer. The remainder of the program runs smoothly.

g) Following completion of *each* of the 5 sections:
- ♦ Conversions of SI Units
- ♦ Tablets & Capsules
- ♦ Liquid Medicines
- ♦ Injections
- ♦ Intra Venous Infusions

I would suggest that you attempt the practice questions relevant to that section, included within the dosage calculation folder - these are typical of the questions included in the actual assessment. The answers to the practice questions are included in the rear of the folder. Additionally you may find it useful to use the *contextualised photographs* included in the folder as an *aide-memoir* when you are away from the computer. Recall that you are permitted to take appropriate *formulae used to calculate the dosage calculations into the assessment with you.* However you are *not permitted to use calculators.*

Finally following completion of the assessment I would be most grateful if you would complete the evaluation questionnaire included with your information letter. Copies of the questionnaire can be obtained from myself or the CFP secretary should you have mislaid the original.

Thank You and Good Luck,

Keith W. Weeks (Lecturer)

Appendix IX

Appendix IX

Analysis of Group X Participants' Cognitive Style in Mathematics (CSM), & Achievements in: GCSE Mathematics and the Numeracy Assessment undertaken at selection

Participant Number	GCSE Math's Grade	Selection Numeracy Assessment (10 x 4 point sections = 40 point total): Total Score	Identified errors relevant to fundamental dosage calculations: Fractions to Decimals	Multiplication	Division	$\frac{A \times B}{C}$	Conversions: Weight	Conversions: Volume	CSM
#01	none	40/40	none	none	none	none	none	none	Intermediate (32)
#02	C	40/40	none	none	none	none	none	none	Intermediate (32)
#03	C	37/40	none	none	1 incorrect	none	2 incorrect	none	Intermediate (34)
#04	B	37/40	none	1 incorrect	none	none	none	none	Intermediate (34)
#05	C	36/40	none	1 incorrect	1 incorrect	none	2 incorrect	none	Intermediate (30)
#06	C	35/40	none	1 incorrect	none	none	2 incorrect	none	Intermediate (33)
#07	C	35/40	none	none	2 incorrect	none	1 incorrect	none	Intermediate (30)
#08	none	35/40	none	none	none	2 incorrect	1 incorrect	none	Grasshopper (36)
#09	C	35/40	none	none	none	none	2 incorrect	none	Inchworm (24)
#10	C	34/40	none	none	none	1 incorrect	3 incorrect	1 incorrect	Intermediate (34)
#11	none	34/40	2 incorrect	none	1 incorrect	none	2 incorrect	none	Intermediate (27)
#12	C	34/40	none	none	2 incorrect	none	none	none	Intermediate (27)
#13	C	33/40	2 incorrect	none	1 incorrect	none	3 incorrect	none	Inchworm (23)
#14	none	31/40	none	1 incorrect	1 incorrect	none	4 incorrect	none	Intermediate (35)
#15	C	30/40	2 incorrect	none	none	1 incorrect	3 incorrect	none	Intermediate (30)
#16	none	28/40	3 incorrect	1 incorrect	1 incorrect	none	2 incorrect	none	Inchworm (16)
#17	C	27/40	1 incorrect	1 incorrect	4 incorrect	none	3 incorrect	1 incorrect	Intermediate (28)
#18	none	26/40	2 incorrect	none	3 incorrect	1 incorrect	3 incorrect	1 incorrect	Inchworm (21)
#19	none	26/40	2 incorrect	1 incorrect	3 incorrect	none	2 incorrect	none	Intermediate (27)
#20	C	25/40	3 incorrect	1 incorrect	1 incorrect	none	3 incorrect	none	Intermediate (29)
#21	C	23/40	3 incorrect	1 incorrect	2 incorrect	none	none	4 incorrect	Intermediate (29)
#22	none	13/40&28/40	none	1 incorrect	2 incorrect	2 incorrect	4 incorrect	none	Inchworm (21)
Total	**Total:111 incorrect**		**20 incorrect**	**10 incorrect**	**25 incorrect**	**7 incorrect**	**42 incorrect**	**7 incorrect**	

Appendix X

Appendix X

Analysis of Group Y Participants' Cognitive Style in Mathematics (CSM) &Achievements in: GCSE Mathematics and the Numeracy Assessment undertaken at selection

Participant Number	GCSE Math's Grade	Selection Numeracy Assessment (10 x 4 point sections = 40 point total)							CSM
		Total Score	Identified errors relevant to fundamental dosage calculations						
			Fractions to Decimals	Multiplication	Division	$\frac{A \times B}{C}$	Conversions		
							Weight	Volume	
#01	C	38/40	none	none	1 incorrect	none	1 incorrect	none	Grasshopper (36)
#02	C	38/40	none	none	1 incorrect	none	none	none	Grasshopper (36)
#03	none	36/40	none	none	none	none	3 incorrect	none	Inchworm (22)
#04	C	35/40	2 incorrect	none	1 incorrect	none	none	none	Grasshopper (39)
#05	none	35/40	none	none	2 incorrect	none	1 incorrect	none	Intermediate (32)
#06	C	34/40	none	none	1 incorrect	none	4 incorrect	none	Intermediate (29)
#07	none	34/40	none	none	1 incorrect	1 incorrect	1 incorrect	none	Intermediate (32)
#08	C	33/40	none	none	none	3 incorrect	3 incorrect	1 incorrect	Intermediate (34)
#09	none	32/40	none	1 incorrect	none	none	2 incorrect	1 incorrect	Inchworm (24)
#10	C	32/40	none	1 incorrect	1 incorrect	none	3 incorrect	none	Inchworm (23)
#11	B	32/40	none	none	1 incorrect	none	none	none	Intermediate (26)
#12	C	31/40	none	none	1 incorrect	none	3 incorrect	none	Inchworm (24)
#13	none	30/40	3 incorrect	none	1 incorrect	none	2 incorrect	none	Intermediate (30)
#14	B	30/40	none	1 incorrect	1 incorrect	4 incorrect	3 incorrect	none	Intermediate (28)
#15	none	28/40	2 incorrect	1 incorrect	3 incorrect	none	1 incorrect	none	Intermediate (27)
#16	none	27/40	4 incorrect	none	2 incorrect	none	3 incorrect	none	Intermediate (34)
#17	B	26/40	1 incorrect	1 incorrect	3 incorrect	none	2 incorrect	1 incorrect	Intermediate (25)
#18	none	24/40	2 incorrect	1 incorrect	2 incorrect	1 incorrect	4 incorrect	2 incorrect	Intermediate (25)
#19	none	24/40	3 incorrect	1 incorrect	1 incorrect	4 incorrect	1 incorrect	none	Intermediate (26)
#20	none	24/40	4 incorrect	1 incorrect	2 incorrect	none	4 incorrect	none	Intermediate (30)
#21	none	20/40&30/40	4 incorrect	none	2 incorrect	1 incorrect	4 incorrect	none	Inchworm (24)
#22	none	19/40&30/40	3 incorrect	1 incorrect	none	1 incorrect	4 incorrect	1 incorrect	Inchworm (19)
Total	**Total:134 incorrect**		**28 incorrect**	**9 incorrect**	**27 incorrect**	**15 incorrect**	**49 incorrect**	**6 incorrect**	

Appendix XI

Appendix XI
Synopsis of statistical analysis

<table>
<tr><th></th><th>Group X</th><th>Group Y</th><th></th></tr>
<tr><td>Computation differences at start of programme
(approx 3% difference)
ANCOVA performed</td><td colspan="2">t-test for independent sample
mean = 32.22/40   mean = 31.04/40
S.D. = 4.9080   S.D. = 4.2591
test t-value = 0.8530
critical t-value: 5% $t_{42,0.025} = 2.021$
no sig diff between mean group scores</td><td></td></tr>
<tr><td>Phase 1</td><td>mean = 28.54/30
S.D. = 2.2195
(CAL only)</td><td>mean = 26.27/30
S.D. = 2.7287
(lesson & tutorial only)</td><td>t-test independent sample
test t-value = 3.030
critical t-value = 1% $t_{42,.005} = 2.704$
sig diff ($p < 0.014$ post ANCOVA)</td></tr>
<tr><td>Phase 2</td><td>mean = 29.69/30
S.D. = 0.7162
(CAL then lesson)</td><td>mean = 28.86/30
S.D. = 1.7264
(lesson then CAL)</td><td>test t-value = 2.0533
crit t-value = 5% $t_{42,\ 0.025} = 2.021$
no sig diff (post ANCOVA)</td></tr>
<tr><td></td><td>t-test paired sample
t = - 2.2431
crit-t value = 5% (2.080)
sig diff ($p < 0.05$)</td><td>t-test paired sample
t = - 4.2797
crit-t value = 0.1% (3.819)
highly sig diff ($p < 0.001$)</td><td></td></tr>
</table>

Appendix XII

Appendix XII

Total Individual Scores achieved on the written Numeracy Assessment undertaken at selection (maximum achievable total score = 40)

Student Number	Group X	Group Y
#01	40	38
#02	40	38
#03	37	36
#04	37	35
#05	36	35
#06	35	34
#07	35	34
#08	35	33
#09	35	32
#10	34	32
#11	34	32
#12	34	31
#13	33	30
#14	31	30
#15	30	28
#16	28	27
#17	27	26
#18	26	24
#19	26	24
#20	25	24
#21	23	30
#22	28	30
	(#22 gained score on resit)	(#21&22 gained score on resit)

$n_1 = 22$
Mean $\bar{X}_1 = 32.2272$
Standard Deviation $SD_1 = 4.9080$

$n_2=22$
Mean $\bar{X}_2 = 31.0454$
Standard Deviation $SD_2 = 4.2591$

Pooled Variance (PV)

$$\mathbf{PV} = \frac{(n_1 - 1)\,SD_1^2 + (n_2 - 1)\,SD_2^2}{(n_1 + n_2) - 2}$$

$$PV = \frac{21(4.9080^2) + 21(4.2591^2)}{(22 + 22) - 2}$$

$$PV = \frac{505.85 + 380.93}{42}$$

$$\mathbf{PV} = \underline{\mathbf{21.113}}$$

Standard Error of Difference (S.E. [diff])

S.E.[diff] = $\sqrt{}$(PV ÷ n_1 + PV ÷ n_2)

S.E.[diff] = $\sqrt{}$(21.113 ÷ 22 + 21.113 ÷ 22)

S.E.[diff] = $\sqrt{1.919}$

S.E.[diff] = 1.3854

Test Value of t

$$\textbf{Test t value} = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{(PV \div n_1 + PV \div n_2)}}$$

$$\text{Test t value} = \frac{32.2272 - 31.0454}{1.3854}$$

Test t value = 0.8530

The Critical t Value

The critical t value for a 5% two tailed test is:

t (n_1 + n_2 - 2, 0.025) with ν (degrees of freedom) = 42

5% $t_{42, 0.025}$ = **2.021**

(i.e., 2.5% divided between the two tails)

Therefore there is no statistical evidence of a significant difference between the *total mean scores achieved on the written selection numeracy assessment* by Group X and Group Y; i.e., there is insufficient evidence to reject the null-hypothesis.

Appendix XIII

Appendix XIII

Total Individual Scores achieved on the written Numeracy Assessment undertaken at selection (maximum score: critical elements for medication dosage computations = 24)

Student Number	Group X	Group Y
#01	24	22
#02	24	23
#03	21	21
#04	23	21
#05	20	21
#06	21	19
#07	21	21
#08	21	17
#09	22	20
#10	19	19
#11	19	23
#12	22	20
#13	18	18
#14	18	15
#15	18	17
#16	17	15
#17	14	16
#18	14	12
#19	16	14
#20	16	13
#21	14	13
#22	15	14
	(#22 gained score on resit)	(#21&22 gained score on resit)

$n_1 = 22$
Mean $\bar{X}_1 = 18.9545$
Standard Deviation $SD_1 = 3.2142$

$n_2 = 22$
Mean $\bar{X}_2 = 17.9090$
Standard Deviation $SD_2 = 3.4765$

Pooled Variance (PV)

$$\mathbf{PV = \frac{(n_1 - 1)\, SD_1^2 + (n_2 - 1)\, SD_2^2}{(n_1 + n_2) - 2}}$$

$$PV = \frac{21(3.2142^2) + 21(3.4765^2)}{(22 + 22) - 2}$$

$$PV = \frac{216.95 + 253.80}{42}$$

$$\mathbf{PV = \underline{11.2083}}$$

Standard Error of Difference (S.E. [diff])

$$\textbf{S.E.[diff]} = \sqrt{(PV \div n_1 + PV \div n_2)}$$

$$\text{S.E.[diff]} = \sqrt{(11.2083 \div 22 + 11.2083 \div 22)}$$

$$\text{S.E.[diff]} = \sqrt{1.0189}$$

$$\textbf{S.E.[diff]} = \underline{\mathbf{1.0094}}$$

Test Value of t

$$\textbf{Test t value} = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{(PV \div n_1 + PV \div n_2)}}$$

$$\text{Test t value} = \frac{18.9545 - 17.9090}{1.0094}$$

$$\textbf{Test t value} = \underline{\mathbf{1.0357}}$$

The Critical t Value

The critical t value for a 5% two tailed test is:

$$\mathbf{t\ (n_1 + n_2 - 2,\ 0.025)\ with\ \nu\ (degrees\ of\ freedom) = 42}$$

$$5\%\ t_{42,\ 0.025} = \mathbf{2.021}$$

(i.e., 2.5% divided between the two tails)

Therefore there is no statistical evidence of a significant difference between the *critical mean scores achieved on the written selection numeracy assessment* by Group X and Group Y; i.e., there is insufficient evidence to reject the null-hypothesis.

Appendix XIV

Appendix XIV

Analysis of Group X Participants' Performance on the Stage 1 Medication Dosage Calculation Assessment (Sole exposure to 'Authentic World'learning environment)

Number of correct answers achieved in each section

Participant Number	Conversions		Oral Medications		Injections	IV Infusions		Total Score
	Weight 8 Questions	Volume 2 Questions	Tablets 3 Questions	Liquid 3 Questions	4 Questions	ml/hour 5 Questions	drops/min 5 Questions	30 Points
#01	8	2	3	3	4	*4*	*4*	*28*
#02	**8**	**2**	**3**	**3**	**4**	**5**	**5**	**30**
#03	**8**	**2**	**3**	**3**	**4**	**5**	**5**	**30**
#04	**8**	**2**	**3**	**3**	**4**	**5**	**5**	**30**
#05	**8**	**2**	**3**	**3**	**4**	**5**	**5**	**30**
#06	8	2	3	*2*	4	5	5	*29*
#07	**8**	**2**	**3**	**3**	**4**	**5**	**5**	**30**
#08	**8**	**2**	**3**	**3**	**4**	**5**	**5**	**30**
#09	**8**	**2**	**3**	**3**	**4**	**5**	**5**	**30**
#10	**8**	**2**	**3**	**3**	**4**	**5**	**5**	**30**
#11	8	2	3	3	4	*2*	*2*	*24*
#12	8	2	3	3	4	*4*	*4*	*28*
#13	8	2	3	*2*	4	*4*	5	*28*
#14	8	2	3	3	4	*4*	*1*	*25*
#15	8	2	3	3	4	*4*	*4*	*28*
#16	**8**	**2**	**3**	**3**	**4**	**5**	**5**	**30**
#17	**8**	**2**	**3**	**3**	**4**	**5**	**5**	**30**
#18	**8**	**2**	**3**	**3**	**4**	**5**	**5**	**30**
#19	8	2	3	3	*3*	*2*	*1*	*22*
#20	**8**	**2**	**3**	**3**	**4**	**5**	**5**	**30**
#21	8	*1*	3	3	*3*	5	5	*28*
#22	8	2	3	3	4	*4*	*4*	*28*

Appendix XV

Appendix XV

Analysis of Group X Participants' Conceptual Errors (Problem Solving); Arithmetical Operation Errors (AO) & Computation Errors (Comp): Stage 1 Assessment

Participant Number	Conversion of SI Unit Errors			Oral Medication & Injection Errors			IV Infusion Errors			Total Errors
	Problem Solving	Arithmetical		Problem Solving	Arithmetical		Problem Solving	Arithmetical		
		AO	Comp		AO	Comp		AO	Comp	
#01	0	0	0	0	0	0	0	0	**2**	**2**
#02	0	0	0	0	0	0	0	0	0	0
#03	0	0	0	0	0	0	0	0	0	0
#04	0	0	0	0	0	0	0	0	0	0
#05	0	0	0	0	0	0	0	0	0	0
#06	0	0	0	0	0	**1**	0	0	0	**1**
#07	0	0	0	0	0	0	0	0	0	0
#08	0	0	0	0	0	0	0	0	0	0
#09	0	0	0	0	0	0	0	0	0	0
#10	0	0	0	0	0	0	0	0	0	0
#11	0	0	0	0	0	0	0	0	**6**	**6**
#12	0	0	0	0	0	0	0	0	**2**	**2**
#13	0	0	0	0	0	**1**	0	0	**1**	**2**
#14	0	0	0	0	0	0	0	0	**5**	**5**
#15	0	0	0	0	0	0	0	0	**2**	**2**
#16	0	0	0	0	0	0	0	0	0	0
#17	0	0	0	0	0	0	0	0	0	0
#18	0	0	0	0	0	0	0	0	0	0
#19	0	0	0	0	0	**1**	0	0	7	**8**
#20	0	0	0	0	0	0	0	0	0	0
#21	0	0	**1**	0	0	**1**	0	0	0	**2**
#22	0	0	0	0	0	0	0	0	**2**	**2**
Total Errors	0	0	**1**	0	0	**4**	0	0	27	**32**

Appendix XVI

Appendix XVI

Analysis of Group Y Participants' Performance on the Stage 1 Medication Dosage Calculation Assessment (Sole exposure to didactic lesson & tutorial with contextualised word problems)

Number of correct answers achieved in each section

Participant Number	Conversions		Oral Medications		Injections	IV Infusions		Total Score
	Weight 8 Questions	Volume 2 Questions	Tablets 3 Questions	Liquid 3 Questions	4 Questions	ml/hour 5 Questions	drops/min 5 Questions	30 Points
#01	8	2	3	3	4	5	5	30
#02	7	2	3	3	4	4	4	27
#03	7	2	3	3	4	5	5	29
#04	8	2	3	3	4	4	4	28
#05	8	2	3	3	4	4	2	26
#06	8	2	3	3	3	3	3	25
#07	7	2	3	3	3	5	5	28
#08	8	2	2	3	4	5	4	28
#09	4	1	3	2	4	4	4	22
#10	6	2	2	3	4	4	5	26
#11	8	2	3	3	4	5	5	30
#12	7	2	3	2	4	5	1	24
#13	8	2	2	1	2	3	2	20
#14	8	2	3	3	4	5	4	29
#15	8	2	3	3	2	5	3	26
#16	8	2	3	3	4	5	4	29
#17	6	1	2	2	3	4	4	22
#18	8	2	2	1	2	5	3	23
#19	8	2	3	2	4	5	4	28
#20	7	2	3	2	4	5	3	26
#21	8	2	3	3	3	3	4	26
#22	8	2	3	1	4	4	4	26

Appendix XVII

Appendix XVII

Analysis of Group Y Participants' Conceptual (Problem Solving) Errors; Arithmetical Operation Errors (AO) & Computation Errors (Comp): Stage 1 Assessment

Participant Number	Conversion of SI Unit Errors			Oral Medication & Injection Errors			IV Infusion Errors			Total Errors
	Problem Solving	Arithmetical		Problem Solving	Arithmetical		Problem Solving	Arithmetical		
		AO	Comp		AO	Comp		AO	Comp	
#01	0	0	0	0	0	0	0	0	0	0
#02	0	1	0	0	0	0	1	0	1	3
#03	0	0	1	0	0	0	0	0	0	1
#04	0	0	0	0	0	0	1	0	1	2
#05	0	0	0	0	0	0	1	0	3	4
#06	0	0	0	0	0	1	4	0	0	5
#07	0	0	1	0	1	0	0	0	0	2
#08	0	0	0	0	0	1	0	0	1	2
#09	0	1	4	0	0	1	0	0	2	8
#10	1	0	1	0	0	1	0	0	1	4
#11	0	0	0	0	0	0	0	0	0	0
#12	0	0	1	1	0	0	0	4	0	6
#13	0	0	0	5	0	0	0	0	5	10
#14	0	0	0	0	0	0	0	0	1	1
#15	0	0	0	1	1	0	0	0	2	4
#16	0	0	0	0	0	0	0	1	0	1
#17	0	0	3	1	0	2	0	0	2	8
#18	0	0	0	1	2	2	0	0	2	7
#19	0	0	0	0	1	0	0	1	0	2
#20	0	0	1	0	0	1	0	0	2	4
#21	0	0	0	0	0	1	0	0	3	4
#22	0	0	0	0	0	2	0	0	2	4
Total Errors	1	2	12	9	5	12	7	6	28	82

Appendix XVIII

Appendix XVIII

Total Individual Scores achieved on a written medication dosage calculation assessment, consisting of: conversion of SI units; computation of tablet, liquid medicine & injections; and intra-venous infusions (maximum achievable score = 30)

Student Number	Group X	Group Y
#01	28	30
#02	30	27
#03	30	29
#04	30	28
#05	30	26
#06	29	25
#07	30	28
#08	30	28
#09	30	22
#10	30	26
#11	24	30
#12	28	24
#13	28	20
#14	25	29
#15	28	26
#16	30	29
#17	30	22
#18	30	23
#19	22	28
#20	30	26
#21	28	26
#22	28	26
	$n_1 = 22$	**n_2=22**
	Mean $\bar{X}_1 = 28.5454$	**Mean $\bar{X}_2 = 26.2727$**
	Standard Deviation $SD_1 = 2.2195$	**Standard Deviation $SD_2 = 2.7287$**

Pooled Variance (PV)

$$\mathbf{PV = \frac{(n_1 - 1)\, SD_1^2 + (n_2 - 1)\, SD_2^2}{(n_1 + n_2) - 2}}$$

$$PV = \frac{21(2.2195^2) + 21(2.7287^2)}{(22 + 22) - 2}$$

$$PV = \frac{103.4497 + 156.3618}{42}$$

$$\mathbf{PV = \underline{6.18598}}$$

Standard Error of Difference (S.E. [diff])

$$\mathbf{S.E.[diff] = \sqrt{(PV \div n_1 + PV \div n_2)}}$$

$$S.E.[diff] = \sqrt{(6.1859 \div 22 + 6.1859 \div 22)}$$

$$S.E.[diff] = \sqrt{0.56235}$$

$$\mathbf{S.E.[diff] = \underline{0.74989}}$$

Test Value of t

$$\mathbf{Test\ t\ value = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{(PV \div n_1 + PV \div n_2)}}}$$

$$Test\ t\ value = \frac{28.5454 - 26.2727}{0.74989}$$

$$\mathbf{Test\ t\ value = \underline{3.030}}$$

The Critical t Value

The critical t value for a 5% two tailed test is:

$$\mathbf{t\ (n_1 + n_2 - 2,\ 0.025)\ with\ \nu\ (degrees\ of\ freedom) = 42}$$

$$5\%\ \mathbf{t}_{42,\ 0.025} = \mathbf{2.021}$$

(i.e., 2.5% divided between the two tails)

$$1\%\ t_{42,\ 0.05} = \underline{\mathbf{2.704}}$$

(i.e., 0.5% divided between the two tails)

Therefore there is clear statistical evidence of a highly significant difference between the *total mean scores achieved on a written medication dosage calculation assessment* by Group X and Group Y on completion of Stage 1. Subsequently the null hypothesis of no significant difference between the two group mean scores *is rejected at the 1% level ($p<.014$ post ANCOVA).*

Appendix IXX

Appendix IXX: Stage 1 Group Scores by Cognitive Style in Mathematics (CSM)

Group X:Sole exposure to 'authentic world' environment				Group Y:Sole exposure to lesson/tutorial with word problem			
CSM	**Participant Number**	**Total Score**	**Mean CSM Group Score**	**CSM**	**Participant Number**	**Total Score**	**Mean CSM Group Score**
Inchworm	#9	**30**	**29.2** 60% achieved 100%	Inchworm	#3	29	**25.5** 0% achieved 100%
Inchworm	#13	28		Inchworm	#9	22	
Inchworm	#16	**30**		Inchworm	#10	26	
Inchworm	#18	**30**		Inchworm	#12	24	
Inchworm	#22	28		Inchworm	#21	26	
Intermediate	#1	28	**28.25** 50% achieved 100%	Inchworm	#22	26	
Intermediate	#2	**30**		Intermediate	#5	26	**26.15** 7.6% achieved 100%
Intermediate	#3	**30**		Intermediate	#6	25	
Intermediate	#4	**30**		Intermediate	#7	28	
Intermediate	#5	**30**		Intermediate	#8	28	
Intermediate	#6	29		Intermediate	#11	**30**	
Intermediate	#7	**30**		Intermediate	#13	20	
Intermediate	#10	**30**		Intermediate	#14	29	
Intermediate	#11	24		Intermediate	#15	26	
Intermediate	#12	28		Intermediate	#16	29	
Intermediate	#14	25		Intermediate	#17	22	
Intermediate	#15	28		Intermediate	#18	23	
Intermediate	#17	**30**		Intermediate	#19	28	
Intermediate	#19	22		Intermediate	#20	26	
Intermediate	#20	**30**		Grasshopper	#1	**30**	**28.33** 33% achieved 100%
Intermediate	#21	28		Grasshopper	#2	27	
Grasshopper	#8	**30**	**30** (100%)	Grasshopper	#4	28	

Appendix XX

Appendix XX

Analysis of Group X Participants' Performance on the Stage 2 Medication Dosage Calculation Assessment (Dual exposure to 'Authentic World' Learning Environment & Lesson/Tutorial)

Number of correct answers achieved in each section

Participant Number	Conversions		Oral Medications		Injections	IV Infusions		Total Score
	Weight 8 Questions	Volume 2 Questions	Tablets 3 Questions	Liquid 3 Questions	4 Questions	ml/hour 5 Questions	drops/min 5 Questions	30 Points
#01	8	2	3	3	4	5	5	30
#02	8	2	3	3	4	5	5	30
#03	8	2	3	3	4	5	5	30
#04	8	2	3	3	4	5	5	30
#05	8	2	3	2	4	5	5	29
#06	8	2	3	3	4	5	5	30
#07	8	2	3	3	4	5	5	30
#08	8	2	3	3	4	5	5	30
#09	8	2	3	3	4	5	5	30
#10	8	2	3	3	3	5	5	29
#11	8	2	3	3	4	5	5	30
#12	8	2	2	1	4	5	5	27
#13	8	2	3	3	4	5	5	30
#14	8	2	3	3	4	5	5	30
#15	8	2	3	3	4	5	5	30
#16	8	2	3	3	4	5	5	30
#17	8	2	3	3	4	5	5	30
#18	8	2	3	3	3	5	5	29
#19	8	2	3	3	4	5	5	30
#20	8	2	3	3	4	5	5	30
#21	8	2	3	2	4	5	5	29
#22	8	2	3	3	4	5	5	30

Appendix XXI

Appendix XXI

Analysis of Group X Participants' Conceptual (Problem Solving) Errors; Arithmetical Operation Errors (AO) & Computation Errors (Comp): During Stage 2 Assessment

Participant Number	Conversion of SI Unit Errors			Oral Medication & Injection Errors			IV Infusion Errors			Total Errors
	Problem Solving	Arithmetical		Problem Solving	Arithmetical		Problem Solving	Arithmetical		
		AO	Comp		AO	Comp		AO	Comp	
#01	0	0	0	0	0	0	0	0	0	0
#02	0	0	0	0	0	0	0	0	0	0
#03	0	0	0	0	0	0	0	0	0	0
#04	0	0	0	0	0	0	0	0	0	0
#05	0	0	0	0	0	**1**	0	0	0	**1**
#06	0	0	0	0	0	0	0	0	0	0
#07	0	0	0	0	0	0	0	0	0	0
#08	0	0	0	0	0	0	0	0	0	0
#09	0	0	0	0	0	0	0	0	0	0
#10	0	0	0	0	0	**1**	0	0	0	**1**
#11	0	0	0	0	0	0	0	0	0	0
#12	0	0	0	0	0	**3**	0	0	0	**3**
#13	0	0	0	0	0	0	0	0	0	0
#14	0	0	0	0	0	0	0	0	0	0
#15	0	0	0	0	0	0	0	0	0	0
#16	0	0	0	0	0	0	0	0	0	0
#17	0	0	0	0	0	0	0	0	0	0
#18	0	0	0	0	**1**	0	0	0	0	**1**
#19	0	0	0	0	0	0	0	0	0	0
#20	0	0	0	0	0	0	0	0	0	0
#21	0	0	0	0	0	**1**	0	0	0	**1**
#22	0	0	0	0	0	0	0	0	0	0
Total Errors	0	0	0	0	1	6	0	0	0	7

Appendix XXII

Appendix XXII

Total Individual Scores achieved on the written medication dosage calculation assessment (maximum achievable score = 30)

Student Number	Stage 1	Stage 2	Difference
#01	28	**30**	-2
#02	**30**	**30**	0
#03	**30**	**30**	0
#04	**30**	**30**	0
#05	**30**	29	1
#06	29	**30**	-1
#07	**30**	**30**	0
#08	**30**	**30**	0
#09	**30**	**30**	0
#10	**30**	29	1
#11	24	**30**	-6
#12	28	27	1
#13	28	**30**	-2
#14	25	**30**	-5
#15	28	**30**	-2
#16	**30**	**30**	0
#17	**30**	**30**	0
#18	**30**	29	1
#19	22	**30**	-8
#20	**30**	**30**	0
#21	28	29	-1
#22	28	**30**	-2
Mean	**28.5454**	**29.6818**	**-1.1364 ($\bar{x}_d$)**
SD	**2.2195**	**0.7162**	**2.3763 (σ_d)**

The Test Statistic

$$t = \frac{\bar{x}_d}{\sigma_d / \sqrt{n}}$$

$$t = \frac{-1.1364}{2.3763 / \sqrt{22}}$$

$$t = \frac{-1.1364}{0.5066}$$

$$t = \underline{-2.2431}$$

The Critical t Value

The critical t value for a 5% two tailed test is:

$t_{21,\,0.025}$ = **2.080**

(i.e., 2.5% divided between the two tails)

Therefore there is sufficient evidence to *reject the null hypothesis at the 5% level*

($p < 0.05$), and to conclude that there was **a significant if moderate improvement in the total mean scores** of students exposed to the computer based 'authentic world' learning environment, followed by the didactic lesson and tutorial, as compared to sole exposure to the based 'authentic world' learning environment.

Appendix XXIII

Appendix XXIII

Analysis of Group Y Participants' Performance on the Stage 2 Medication Dosage Calculation Assessment (Dual exposure to lesson/tutorial incorporating contextualised word problems & 'Authentic World' Learning Environment)

Number of correct answers achieved in each section

Participant Number	Conversions		Oral Medications		Injections	IV Infusions		Total Score
	Weight 8 Questions	Volume 2 Questions	Tablets 3 Questions	Liquid 3 Questions	4 Questions	ml/hour 5 Questions	drops/min 5 Questions	30 Points
#01	8	2	3	3	4	5	5	30
#02	8	2	3	3	4	5	5	30
#03	8	2	3	3	4	5	5	30
#04	8	2	3	3	4	5	5	30
#05	8	2	3	3	4	5	5	30
#06	8	2	3	2	4	3	3	25
#07	8	2	3	3	4	5	5	30
#08	8	2	3	3	2	5	4	27
#09	8	2	3	3	4	4	4	28
#10	8	2	3	3	3	5	4	28
#11	8	2	3	3	4	5	5	30
#12	8	2	3	3	2	5	5	28
#13	8	2	3	3	4	5	5	30
#14	8	2	3	3	4	5	5	30
#15	8	2	3	3	4	5	5	30
#16	8	2	3	3	4	5	5	30
#17	8	2	3	3	4	5	5	30
#18	8	2	2	2	4	4	3	25
#19	8	2	2	3	3	4	4	26
#20	8	2	3	3	4	5	5	30
#21	8	2	3	3	4	5	5	30
#22	8	2	3	3	3	4	5	28

Appendix XXIV

Appendix XXIV

Analysis of Group Y Participants' Problem Solving Conceptual Errors; Arithmetical Operation Errors(AO) & Computation Errors (Comp): Stage 2 Assessment

Participant Number	Conversion of SI Unit Errors			Oral Medication & Injection Errors			IV Infusion Errors			Total Errors
	Problem Solving	Arithmetical AO	Arithmetical Comp	Problem Solving	Arithmetical AO	Arithmetical Comp	Problem Solving	Arithmetical AO	Arithmetical Comp	
#01	0	0	0	0	0	0	0	0	0	0
#02	0	0	0	0	0	0	0	0	0	0
#03	0	0	0	0	0	0	0	0	0	0
#04	0	0	0	0	0	0	0	0	0	0
#05	0	0	0	0	0	0	0	0	0	0
#06	0	0	0	0	0	1	0	0	4	5
#07	0	0	0	0	0	0	0	0	0	0
#08	0	0	0	0	1	1	0	0	1	3
#09	0	0	0	0	0	0	0	0	2	2
#10	0	0	0	0	1	0	0	0	1	2
#11	0	0	0	0	0	0	0	0	0	0
#12	0	0	0	0	2	0	0	0	0	2
#13	0	0	0	0	0	0	0	0	0	0
#14	0	0	0	0	0	0	0	0	0	0
#15	0	0	0	0	0	0	0	0	0	0
#16	0	0	0	0	0	0	0	0	0	0
#17	0	0	0	0	0	0	0	0	0	0
#18	0	0	0	0	2	0	0	0	3	5
#19	0	0	0	0	0	2	0	0	2	4
#20	0	0	0	0	0	0	0	0	0	0
#21	0	0	0	0	0	0	0	0	0	0
#22	0	0	0	0	1	0	0	0	1	2
Total Errors	0	0	0	0	7	4	0	0	14	25

Appendix XXV

Appendix XXV

Total Individual Scores achieved on the written medication dosage calculation assessment (maximum achievable score = 30)

Student Number	Stage 1	Stage 2	Difference
#01	**30**	**30**	0
#02	27	**30**	-3
#03	29	**30**	-1
#04	28	**30**	-2
#05	26	**30**	-4
#06	25	25	0
#07	28	**30**	-2
#08	28	27	1
#09	22	28	-6
#10	26	28	-2
#11	**30**	**30**	0
#12	24	28	-4
#13	20	**30**	-10
#14	29	**30**	-1
#15	26	**30**	-4
#16	29	**30**	-1
#17	22	**30**	-8
#18	23	25	-2
#19	28	26	2
#20	26	**30**	-4
#21	26	**30**	-4
#22	26	28	-2
Mean	**26.2727**	**28.8636**	**-2.5909 ($\bar{x}_d$)**
SD	**2.7287**	**1.7264**	**2.8395 (σ_d)**

The Test Statistic

$$t = \frac{\bar{x}_d}{\sigma_d / \sqrt{n}}$$

$$t = \frac{-2.5909}{2.8395 / \sqrt{22}}$$

$$t = \frac{\mathbf{-2.5909}}{\mathbf{0.6053}}$$

$$t = \underline{\mathbf{-4.2797}}$$

<u>The Critical t Value</u>

The critical t value for a 5% two tailed test is:

$t_{21,\, 0.025} = \mathbf{2.080}$

(i.e., 2.5% divided between the two tails)

The critical t value for a $\frac{1}{10}$ of 1% two tailed test is:

$t_{21,\, 0.0005} = \mathbf{3.819}$

(i.e., $\frac{1}{10}$ of 1% divided between the two tails)

Therefore there is sufficient evidence to reject the null hypothesis at the $\frac{1}{10}$ of 1% level ($p<.001$), and to conclude that there was a very highly significant improvement in the total mean scores of students initially exposed to the lesson and tutorial followed by the 'Authentic World' learning environment; as opposed to sole exposure to the lesson and group tutorial - incorporating contextualised word problems. However as will be discussed later, whilst the magnitude of improvement was greater for Group Y than for Group X, between stages 1 and 2, the latter mean groups' scores were significantly higher. This having important implications for the sequencing of relevant teaching strategies.

Appendix XXVI

Appendix XXVI

Total Individual Scores achieved on Stage 2 written medication dosage calculation assessment, consisting of: conversion of SI units; computation of tablet, liquid medicine & injections; and intra-venous infusions (maximum achievable score = 30)

Student Number	Group X	Group Y
#01	30	30
#02	30	30
#03	30	30
#04	30	30
#05	29	30
#06	30	25
#07	30	30
#08	30	27
#09	30	28
#10	29	28
#11	30	30
#12	27	28
#13	30	30
#14	30	30
#15	30	30
#16	30	30
#17	30	30
#18	29	25
#19	30	26
#20	30	30
#21	29	30
#22	30	28
	$n_1 = 22$	**$n_2=22$**
	Mean $\bar{X}_1 = 29.6818$	**Mean $\bar{X}_2 = 28.8636$**
	Standard Deviation $SD_1 = 0.7162$	**Standard Deviation $SD_2 = 1.7264$**

Pooled Variance (PV)

$$\mathbf{PV = \frac{(n_1 - 1)\, SD_1^2 + (n_2 - 1)\, SD_2^2}{(n_1 + n_2) - 2}}$$

$$PV = \frac{21(0.7162^2) + 21(1.7264^2)}{(22 + 22) - 2}$$

$$PV = \frac{10.7717 + 62.5895}{42}$$

$$\mathbf{PV = \underline{1.74669}}$$

Standard Error of Difference (S.E. [diff])

$$\mathbf{S.E.[diff] = \sqrt{(PV \div n_1 + PV \div n_2)}}$$

$$S.E.[diff] = \sqrt{(1.74669 \div 22 + 1.74669 \div 22)}$$

$$S.E.[diff] = \sqrt{0.15879}$$

$$\mathbf{S.E.[diff] = \underline{0.39848}}$$

Test Value of t

$$\textbf{Test t value} = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{(PV \div n_1 + PV \div n_2)}}$$

$$\text{Test t value} = \frac{29.6818 - 28.8636}{0.39848}$$

$$\textbf{Test t value} = \underline{\mathbf{2.0533}}$$

The Critical t Value

The critical t value for a 5% two tailed test is:

$$\mathbf{t\ (n_1 + n_2 - 2,\ 0.025)\ \text{with}\ \nu\ \text{(degrees of freedom)} = 42}$$

$$5\%\ t_{42,\ 0.025} = \mathbf{2.021}$$

(i.e., 2.5% divided between the two tails)

Therefore prior to adjustment via ANCOVA, there was statistical evidence of a significant difference between the *total mean scores achieved on a written medication dosage calculation assessment* by Group X and Group Y during Stage 2. Subsequently prior to adjustment, the null hypothesis of no significant difference between the two group mean scores *was rejected at the 5% level ($p<.05$).*

However following adjustment via ANCOVA, there was no evidence of a significant difference between the group means ($p > 0.066$).

Appendix XXVII

Appendix XXVII: Stage 2 Group Scores by Cognitive Style in Mathematics (CSM) [Brackets = Stage 1 scores]

Group X: CAL followed by Lesson & Tutorial				Group Y: Lesson & Tutorial followed by CAL			
CSM	Participant Number	Total Score	Mean CSM Group Score	CSM	Participant Number	Total Score	Mean CSM Group Score
Inchworm	#9	**[30[30**	80%	Inchworm	#3	[29] **30**	33%
Inchworm	#13	[28] **30**	achieved 100%	Inchworm	#9	[22] 28	achieved 100%
Inchworm	#16	**[30] 30**	**29.8**	Inchworm	#10	[26] 28	**28.66**
Inchworm	#18	**[30]** 29	**[29.2]**	Inchworm	#12	[24] 28	**[25.5]**
Inchworm	#22	[28] **30**		Inchworm	#21	[26] **30**	
Intermediate	#1	[28] **30**		Inchworm	#22	[26] 28	
Intermediate	#2	**]30] 30**		Intermediate	#5	[26] **30**	
Intermediate	#3	**[30] 30**		Intermediate	#6	[25] 25	
Intermediate	#4	**]30] 30**		Intermediate	#7	[28] **30**	
Intermediate	#5	**[30]** 29		Intermediate	#8	[28] 27	
Intermediate	#6	[29] **30**	75%	Intermediate	#11	**[30] 30**	69%
Intermediate	#7	**[30] 30**	achieved 100%	Intermediate	#13	[20] **30**	achieved 100%
Intermediate	#10	**[30]** 29	**29.625**	Intermediate	#14	[29] **30**	**28.7**
Intermediate	#11	[24] **30**	**[28.25]**	Intermediate	#15	[26] **30**	**[26.15]**
Intermediate	#12	[28] 27		Intermediate	#16	[29] **30**	
Intermediate	#14	[25] **30**		Intermediate	#17	[22] **30**	
Intermediate	#15	[28] **30**		Intermediate	#18	[23] 25	
Intermediate	#17	**[30] 30**		Intermediate	#19	[28] 26	
Intermediate	#19	[22] **30**		Intermediate	#20	[26] **30**	
Intermediate	#20	**[30] 30**		Grasshopper	#1	**[30] 30**	(100%)
Intermediate	#21	[28] 29		Grasshopper	#2	[27] **30**	**30**
Grasshopper	#8	**[30] 30**	**[30] 30** (100%)	Grasshopper	#4	[28] **30**	**[28.33]**

Appendix XXVIII

Synopsis of Case Studies

<table>
<tr><td>Pseudonym, group and number :

Ruth (Group X; #2)</td><td>Age:

43</td><td>Sex:

Female</td></tr>
<tr><td>Achievement level in GCSE Mathematics:

Grade 'C'</td><td>CSM:

Intermediate</td><td>Branch:

Mental Health</td></tr>
<tr><td colspan="3">Performance during Numeracy Assessment undertaken at selection:

Score 40/40: Ruth demonstrated no mathematical defects or errors.</td></tr>
<tr><td colspan="3">Performance during Stages 1 & 2 of the college based investigation:

Stage 1 Score: 30/30
Stage 2 Score: 30/30

Summary: Following exposure to the 'Authentic World' learning environment and screenshot photographs Ruth demonstrated no errors during the Stage 1 assessment. Subsequently these skills were retained following exposure to the didactic teacher led lesson and group tutorial. Therefore there was evidence to suggest that the mathematical skills demonstrated in the numeracy assessment undertaken at selection were retained during both the Stage 1 and Stage 2 written assessments.</td></tr>
<tr><td colspan="3">Performance during the clinical based phase of the investigation:

Summary - No errors demonstrated: Ruth demonstrated clear familiarity with the prescription charts, tablet containers and liquid medicine containers. She recognised and recalled that the standard administration set delivered 20 drops per millilitre when delivering clear IV fluid. Ruth was very meticulous with all her calculations, and accurately and adeptly calculated all tablet and liquid medicine dosages, and IV infusion volume and drop rates. All computations were set up correctly and calculated using the methods demonstrated in the 'Authentic World' learning environment program.</td></tr>
</table>

<table>
<tr><td>Pseudonym, group and number :

Lisa (Group Y; #4)</td><td>Age:

19</td><td>Sex:

Female</td></tr>
<tr><td>Achievement level in GCSE Mathematics:

Grade 'C'</td><td>CSM:

Grasshopper</td><td>Branch:

Child</td></tr>
<tr><td colspan="3">Performance during Numeracy Assessment undertaken at selection:

Score: 35/40

♦ Error when: converting fractions to decimals
♦ Error of: integer division</td></tr>
<tr><td colspan="3">Performance during Stage 1 & 2 of the college based investigation:

Stage 1 score: 28/30
Stage 2 score: 30/30

Summary: Following exposure to the didactic lesson and group tutorial Lisa demonstrated no evidence of errors when converting fractions to decimals. However she demonstrated: a minor computation error when calculating intravenous infusion volume rate; and a conceptual error when calculating intravenous infusion drop rate. Subsequently following exposure to the 'Authentic World' learning environment and screenshot photographs, Lisa demonstrated none of the above computation or conceptual errors.</td></tr>
<tr><td colspan="3">Performance during the clinical based phase of the investigation:

Summary - No errors demonstrated: Lisa was very confident and demonstrated clear familiarity with the prescription charts and liquid medicine containers. She recognised the different intravenous infusion administration sets stored on the ward, and clearly recalled the difference between the drops per millilitre delivered by each set. She accurately calculated all dosages and infusion rates with ease; however with the exception of one calculation (Phenobarbitone 15 mg - which was calculated mentally), all calculations were computed with pencil and paper. This being performed using the formulae utilised in the 'Authentic World' learning environment.</td></tr>
</table>

<table>
<tr><td>Pseudonym, group and number :

Nicola (Group Y; #11)</td><td>Age:

19</td><td>Sex:

Female</td></tr>
<tr><td>Achievement level in GCSE Mathematics:

Grade 'B'</td><td>CSM:

Intermediate</td><td>Branch:

Child</td></tr>
<tr><td colspan="3">Performance during Numeracy Assessment undertaken at selection:

Score: 32/40

♦ Error of: integer division</td></tr>
<tr><td colspan="3">Performance during Stage 1 & 2 of the college based investigation:

Stage 1 score: 30/30
Stage 2 score: 30/30

Summary: Following exposure to the didactic lesson and group tutorial Nicola demonstrated none of the minor miscomputation problems evidenced in the numeracy assessment undertaken at selection. Subsequently this skill was retained following exposure to the 'Authentic World' learning environment and screenshot photographs. Therefore there was evidence to support a positive relationship between exposure to the didactic lesson and group tutorial and the participant's performance on the written dosage calculation assessment. Moreover this performance was retained throughout Stage 2 of the study.</td></tr>
<tr><td colspan="3">Performance during the clinical based phase of the investigation:

Summary - No errors demonstrated: Nicola clearly demonstrated familiarity with the prescription charts, tablet containers and liquid medicine containers. She recognised the different intravenous infusion administration sets stored on the ward, and recalled that the standard and microdrop administration sets deliver 20 drops per millilitre and 60 drops per millilitre respectively, when delivering clear IV fluid. Nicola was extremely confident and adept with all calculations, each being set up and calculated with pen and paper, as demonstrated within the 'Authentic World' learning environment.</td></tr>
</table>

Pseudonym, group and number :	Age:	Sex:
Rachael (Group Y; 12)	19	Female
Achievement level in GCSE Mathematics:	**CSM:**	**Branch:**
Grade 'C'	Inchworm	Adult

Performance during Numeracy Assessment undertaken at selection:

Score: 31/40

- Uncertain knowledge of: converting SI units of weight
  integer division

Performance during Stage 1 & 2 of the college based investigation:

Stage 1 score: 24/30
Stage 2 score: 28/30

Summary: Following exposure to the didactic lesson and group tutorial Rachael demonstrated evidence of computation errors when converting SI units of weight; arithmetical operation errors when converting fractions to decimals; a conceptual error when calculating a liquid medication dose, and evidence of uncertain knowledge during cross multiplication of whole number (integer) & fractions during computation of I.V. drop rate per minute

Subsequently following exposure to the 'Authentic World' learning environment, there was no evidence of computation errors when converting SI units of weight; neither was there evidence of any conceptual errors, or uncertain knowledge during cross multiplication of whole number (integer) & fractions during computation of I.V. drop rate per minute.

However the arithmetical operation manifested in Stage 1 when converting fractions to decimals remained resistant to change in Stage 2, when calculating injection dosages.

Performance during the clinical based phase of the investigation:

Summary - Committed two arithmetical operation errors when converting fractions to decimal equivalents: Rachael was rather nervous but demonstrated familiarity with the prescription charts, tablet containers and liquid medicine containers. She recognised and recalled that the standard administration set delivered 20 drops per millilitre when delivering clear IV fluid. Rachael took an extremely long time in performing many calculations, this due to an inability to perform short or long division. In common with computations performed during the written assessments this took the form of listing and adding long columns (the number dictated by the relevant denominator) of estimated multiples (the suspected quotient/answer) until the sum of the numerator was found: e.g. (see over page):

Problem:

$$\frac{1000}{12}$$

Calculated as: *80 was the suspected/estimated quotient; therefore a column of 80* x *(12 the denominator)is listed and added:*

80
80
80
80
80
80
80
80
80
80
80
80
960 remainder 40

3 x 12 = 36

*80 + 3 = **83 (answer)***

However she finally accurately calculated all tablet and liquid medicine dosages, and IV infusion volume and drop rates. She *very slowly but accurately* calculated two IV infusion volume per hour, and drops per minute calculations (although only 20 drop per millilitre infusion sets were in use on the ward during this period). Despite accurately calculating the metoclopramide injection dose she demonstrated arithmetical operation errors during both the insulin injection calculations. For example when dividing 24/100 she divided the numerator into the denominator ('roughly 4'), and then preceded this with a decimal point and a zero, i.e., an answer of 0.4. Despite an initial explanation and demonstration of the relationship between the gauge and sub-divisions of an insulin syringe; and the strength of 100iu/millilitre insulin, Rachael failed to comprehend the relationship between international units and volume. Subsequently following further demonstrations she began to recognise the relevant simplicity of international unit:volume ratios, and the *critical requirement* for drawing up the *correct volume*.........however she recognised that much more practice at both calculating and preparing insulin doses was required.

<table>
<tr><th>Pseudonym, group and number :

Steven (Group Y; #13)</th><th>Age:

26</th><th>Sex:

Male</th></tr>
<tr><td>Achievement level in GCSE Mathematics:

None</td><td>CSM:

Intermediate</td><td>Branch:

Mental Health</td></tr>
<tr><td colspan="3">Performance during Numeracy Assessment undertaken at selection:

Score: 30/40

♦ Error of: integer division

♦ Errors when: converting fractions to decimals
converting SI units of weight</td></tr>
<tr><td colspan="3">Performance during Stage 1 & 2 of the college based investigation:

Stage 1 score: 20/30
Stage 2 score: 30/30

Summary: Following exposure to the didactic lesson and group tutorial Steven demonstrated no computation errors when converting SI units of weight. There was no evidence of computation errors when converting fractions to decimal equivalents However there was evidence of substantial conceptual errors when calculating tablet & capsule and liquid medicine dosage calculations; and evidence of computation errors of integer division and multiplication when calculation IV infusions.

Subsequently following exposure to the 'Authentic World' learning environment, there was no evidence of any of the above conceptual, or multiplication and division computation errors. Therefore there is clear evidence that exposure to the 'Authentic World' learning environment assisted the participant to overcome in particular the previously manifested conceptual errors.</td></tr>
<tr><td colspan="3">Performance during the clinical based phase of the investigation:

Steven suffered an exacerbation of a chronic health problem and was unable to participate in the clinical based phase of the investigation. However he did consent to participation in the interview process.</td></tr>
</table>

<table>
<tr><td>Pseudonym, group and number :

Karen (Group X; #17)</td><td>Age:

19</td><td>Sex:

Female</td></tr>
<tr><td>Achievement level in GCSE Mathematics:

Grade ‘C’</td><td>CSM

Intermediate</td><td>Branch:

Adult</td></tr>
<tr><td colspan="3">Performance during Numeracy Assessment undertaken at selection:

Score: 27/40

♦ Uncertain knowledge of: converting fractions to decimals
integer division
converting SI units of volume

♦ Miscomputation of: integer multiplication

♦ Error when: converting SI units of weight</td></tr>
<tr><td colspan="3">Performance during Stage 1 & 2 of the college based investigation:

Stage 1 score: 30/30
Stage 2 score: 30/30

Summary: Following exposure to the ‘Authentic World’ learning environment and screenshot photographs Karen demonstrated none of the aspects of uncertain knowledge, or miscomputations evidenced in the numeracy assessment undertaken at selection. Subsequently these skills were retained following exposure to the didactic lesson and group tutorial. Therefore there was evidence to support a positive relationship between exposure to the ‘Authentic World’ learning environment and the participant’s performance on the written dosage calculation assessment. Moreover this performance was retained throughout Stage 2 of the study.</td></tr>
<tr><td colspan="3">Performance during the clinical based phase of the investigation:

Summary - No errors committed: Karen was very confident and demonstrated clear familiarity with the prescription charts, tablet containers and injection ampoules. She recognised the different intravenous infusion administration sets stored on the ward, and clearly recalled the difference between the drops per millilitre delivered by each set. Subsequently she accurately calculated all dosages and infusion rates with ease.</td></tr>
</table>

<table>
<tr><td>Pseudonym, group and number :

Susan (Group X; #18)</td><td>Age:

26</td><td>Sex:

Female</td></tr>
<tr><td>Achievement level in GCSE Mathematics:

None</td><td>CSM:

Inchworm</td><td>Branch:

Mental Health</td></tr>
<tr><td colspan="3">Performance during Numeracy Assessment undertaken at selection:

Score 26/40</td></tr>
<tr><td colspan="3">Performance during Stage 1 & 2 of the college based investigation:

Stage 1 score: 30/30
Stage 2 score: 29/30

Summary: Following exposure to the 'Authentic World' learning environment Susan demonstrated no evidence of miscomputation of: integer division, or of multiple integer computation in formulae. Neither was there any evidence of errors when converting SI units of weight and volume. However Susan resisted converting fractions to their decimal equivalent. Subsequently following exposure to the didactic lesson and group tutorial (and a dictate that all fractions were to be represented as their decimal equivalent), the Stage 2 assessment revealed her arithmetical operation error when converting between fractions and decimal equivalents.</td></tr>
<tr><td colspan="3">Performance during the clinical based phase of the investigation:

Summary - committed one arithmetical operation error: Susan was generally very confident and demonstrated clear familiarity with the prescription charts, tablet containers, liquid medicine containers and injection ampoules. With one exception all calculations were performed mentally with no use of pencil and paper. However Susan committed an arithmetical operation error during one injection dosage calculation, which was identical to the arithmetical operation error manifested in the Stage 2 written assessment. Following twenty minutes of one to one tuition and practice, Susan demonstrated a clear understanding of relevant division skills, and the convention for conversion between fractions and decimal equivalents.</td></tr>
</table>

<table>
<tr><td>Pseudonym, group and number :

Kerys (Group Y; #19)</td><td>Age:

21</td><td>Sex:

Female</td></tr>
<tr><td>Achievement level in GCSE Mathematics:

None</td><td>CSM:

Intermediate</td><td>Branch:

Adult</td></tr>
<tr><td colspan="3">Performance during Numeracy Assessment undertaken at selection:

Score: 24/30

♦ Miscomputation of: integer multiplication
multiple integer computation in formulae

♦ Miscomputation when: converting fractions to decimals
multiple integer computation in formulae
converting SI units of weight</td></tr>
<tr><td colspan="3">Performance during Stage 1 & 2 of the college based investigation:

Stage 1 score: 28/30
Stage 2 score: 26/30

Summary: Following exposure to the didactic lesson and group tutorial Kerys demonstrated no miscomputations of integer multiplication or of multiple integer computation in formulae. Neither was there evidence of errors when: converting fractions to decimal equivalents; when performing multiple integer computation in formulae; or when converting SI units of weight. However there was evidence of arithmetical operation errors relevant to the convention for decimal point positioning, when calculating liquid medicine dosages, and intravenous fluid drop rates.

Subsequently following exposure to the 'Authentic World' learning environment, there was evidence of computation errors of integer division when calculating tablet & capsule doses, injection doses and intravenous infusion fluid volume rates. The participant now demonstrated an understanding of the convention for decimal point positioning; however she was clearly uncertain of her ability to perform division of integers, and supplied a range of answers to posed problems, usually ending in a guess.</td></tr>
<tr><td colspan="3">Performance during the clinical based phase of the investigation:

Summary - one computation error: Kerys was rather nervous however she demonstrated familiarity with the prescription charts, tablet containers and liquid medicine containers. She recognised the different intravenous infusion administration sets stored on the ward, and recalled that the standard administration set delivered 20 drops per millilitre when delivering clear IV fluid. Kerys pondered over most calculations, however she accurately calculated all tablet and liquid medicine dosages; this including the Captopril dosage where she recognised the ratio-proportional relationship between 6.25:12.5 and the $\frac{1}{2}$ Tablet correct dose. She slowly but accurately calculated two IV infusion volume per hour,</td></tr>
</table>

and drops per minute calculations (although only 20 drop per millilitre infusion sets were in use on the ward during this period). However Kerys miscomputed the Pethidine injection calculation as [1.05]. Here following setting-up the calculation correctly, she correctly computed 150/100 as 1 remainder 50; however following correct placement of the decimal point (to the right of the [1.] in the quotient) she incorrectly stated 50 divided by 100 will not go...so I put a 0 [1.0 in the quotient] and then add a nought to the 50...and say 500 divided by 100 equals 5...so...[1.05]. Kerys was shown the convention for calculating the correct Pethidine dose [1.5 ml]....however it was clear that she required further practice in order to both gain confidence in her ability and to understand and perform computations of this type.

Pseudonym, group and number :	Age:	Sex:
Kim (Group Y; #22)	21	Female
Achievement level in GCSE Mathematics:	**CSM:**	**Branch:**
None	Inchworm	Child

Performance during Numeracy Assessment undertaken at selection:

Score: 19/40 and 30/40 achieved on resit

- Uncertain knowledge of: converting SI units of weight
- Miscomputation of: integer multiplication; multiple integer computation in formulae
- Errors when: converting fractions to decimals; converting SI units of weight; converting SI units of volume

Performance during Stage 1 & 2 of the college based investigation:

Stage 1 score: 26/30
Stage 2 score: 28/30

Summary: Following exposure to the didactic lesson and group tutorial Kim demonstrated no uncertain knowledge or errors when converting SI units of weight and volume. There was no evidence of miscomputation of integer multiplication; and there was no direct evidence of errors when converting fractions to decimal equivalents However there was evidence of errors regarding the ratio-proportional relationship of liquid medicine dosages (it was not possible to categorise the error type as no computation method was demonstrated); and evidence of computation errors of integer division when calculating intravenous fluid volumes.

Subsequently following exposure to the' Authentic World' learning environment, (and a stipulation that all computation methods were to be shown) there was no evidence of errors regarding the ratio-proportional relationship of liquid medicine dosages. However there was now clear evidence of an arithmetical operation error when converting between fractions and decimal equivalents. Kim also continued to make minor computation errors in integer division, this being related to miscomputation of, or failure to carry remainders and was generally non-critical in magnitude.

Performance during the clinical based phase of the investigation:

Summary - while there was no opportunity to test for arithmetical operation errors, Kim committed two computation errors: Kim was clearly anxious. However she demonstrated familiarity with the prescription charts, tablet containers and liquid medicine containers. The I.V. injection preparations were pre-prepared by the Pharmacy Department, and following an explanation of the administration protocol, Kelly was able to accurately calculate the required volume (however the rate of I.V. administration via volumetric pump was not assessed). She accurately converted between grams and milligrams; and accurately calculated a simple tablet dosage problem. Kim recognised the standard intravenous infusion administration set used on the ward, and recalled the drops per millilitre delivered by this set. Subsequently she accurately calculated the infusion drop rate with ease.

She accurately calculated a range of liquid medicine dosages, using the dosage calculation formula illustrated in the' Authentic World' learning environment. However during one dosage problem she was unable to divide integer numbers where the divisor contained a decimal point; and during one dosage problem was unable to cancel and simplify or utilise the principle of highest common denominator in equations containing large numbers. She demonstrated a clear and accurate understanding of formulae use, but in both the above dosage problems, her poor computation skills prevented her from concluding the answer.

Appendix IXXX

Clinical Based Phase

Data Collection Sheet

Performance & Errors demonstrated during - Medication dosage calculation episodes observed in Clinical Practice

Conversions of SI Units

Prescribed SI Unit	Dispensed SI Unit	Quantity/Volume of Drug to be Administered	Quantity/Volume of Drug Calculated by Participant

Administration of Tablets & Capsules

Prescribed Drug	Prescribed Dose	Correct number of tablets/capsules	Calculated number of tablets/capsules

Administration of Liquid Medicines

Prescribed Drug	Prescribed Dose	Correct volume of drug	Calculated volume of drug

Administration of Injections

Prescribed Drug	Prescribed Dose	Correct volume of drug	Calculated volume of drug

Administration of Intra-Venous Infusions

Prescribed Volume	Prescribed infusion time	Correct volume/drop rate	Calculated volume/drop rate

Comments on participants' performance and any residual transfer or manifestation of errors in clinical practice

Appendix XXX

Publications and Abstracts of Presentations Arising out of the Thesis

Abstract: Paper presented at the RCN Research Society Conference (Sheffield 2000)

Type of Presentation: Concurrent session
Theme: Education

Key words: developing fundamental cognitive nursing skills, bridging the theory-practice divide, constructivism, fallibilist philosophy of teaching, nurses as Computer Assisted Learning (CAL) program designers.

Title: Avoiding medication dosage calculation errors: The development of computer based learning designed to improve fundamental medication dosage problem-solving skills.

This study stemmed from joint education and clinical staff concerns, regarding the often bizarre errors manifested by novice nursing students during written fundamental dosage calculation assessments. Assessments and tutorials consistently revealed poor problem-comprehension and both conceptual problem-solving and computational errors. Subsequently following development of a contextualised interactive CAL-program, based on constructivist principles: 2 groups of 22 randomly selected novice students were exposed to a repeat-measure experiment, triangulated with 9 qualitative clinical case-studies. The presentation focuses on:

1. Conceptual difficulties encountered by novice students when learning dosage calculation problem-solving skills, via didactic methods and contextualised word-problems.
2. The educational-rationale of the CAL program.
3. The results of a college-based experiment and college/clinical-based assessments

Selected findings emphasise the process of problem-comprehension and problem-solving skill development, via assisting movement of novice students from an iconic to a symbolic mode of reasoning. This via an interactive CAL/CD-ROM-program designed to link digital photographs of concrete elements situated in clinical nursing practice, with mathematical formulae used in solving fundamental medication dosage calculation problems.

4 main findings are presented & supported by statistical & illustrative data extracts:

- Written assessments revealed that following sole exposure to didactic teaching methods, 45% of participants committed conceptual problem-solving errors. Conversely exposure to the CAL program facilitated elimination of problem-solving errors among all 44 participants.
- Subsequently this revealed 9/44 participants who manifested deeply-entrenched computational problems.
- In contrast to previous reports, clinical assessment of students revealed that performance on written assessments was predictive of performance during clinical problem-solving scenarios.
- Interview data revealed that visualisation of both iconic and symbolic features, substantially enhanced problem-comprehension and both written- and clinical-based problem-solving skills.

These findings contribute to education theory through illustrating how constructivist-strategies assist novice nursing students to: develop fundamental cognitive nursing skills, and to bridge the divide between theory and practice.

Written drug dosage errors made by students: the threat to clinical effectiveness and the need for a new approach

K. W. Weeks, P. Lyne and C. Torrance

This paper forms part of a series concerned with the establishment of the mathematical competence necessary for the safe calculation of medication dosages and hence for safe and clinically effective nursing practice.

It describes the preliminary work that led up to the development of a new computer based constructivist approach to teaching medication dosage calculation problem solving skills. This arose from observations of the errors committed by novice nursing students in a large UK School of Nursing during written assessments of dosage calculation ability.

The paper begins by describing the nature of conceptions which underlie the computation errors observed during initial student selection and early studies at the school. Examples of arithmetic and miscomputation errors are documented. The nature of these errors revealed the need for a new approach to initial numeracy assessment and teaching of computation skills. This was further borne out by analysis of conceptual errors, which contested the usefulness of the existing teaching approach based on didactic methods and abstract word problems.

The paper concludes by introducing the constructivist view which informed the development of new computer based learning materials. The nature of these materials and their evaluation in the college and clinical settings are described in the subsequent papers.

Keywords: developing fundamental cognitive nursing skills, narrowing the theory-practice divide, education for clinical effectiveness

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INTRODUCTION

Any miscalculation of medication dosage represents a potential threat to both patient safety and clinical effectiveness. One of the earliest documented reports of 'graduate nurses having much difficulty with math calculation' occurred six decades ago (Faddis 1939). As we move into the third millennium there remains evidence from the international nursing literature that medication errors, which include medication dosage calculation errors, continue to be committed by a range of health care professionals (Dean et al. 1995, Ridge et al. 1995, Lesar et al. 1997, Olsen et al. 1997). Due to variations in methods of error rate reporting, caution is needed when interpreting published data (van Leeuwen 1994). Nevertheless during the last decade the reported incidence of medication dosage calculation errors observed in clinical nursing practice varies up to a maximum of 15% of all medication administration errors committed (Ridge et al. 1995). Moreover it is widely believed that the number of medication errors reported at each hospital may be an under-representation (Cooper 1995

Gladstone 1995, Hackel et al. 1996). Therefore it is essential that continued efforts are made in the pre-registration education and clinical domains to develop and promote this critical skill.

Activities with this purpose may be termed *education for clinical effectiveness* since they act as a precursor to effectiveness in clinical practice. This series of papers explores the education processes involved in setting a foundation for the development of clinical effectiveness in the area of medication dosage calculations. The present paper begins with an analysis of the arithmetical skills which are fundamental to medication dosage calculation.

THE RELATIONSHIP BETWEEN ARITHMETIC AND MEDICATION DOSAGE CALCULATIONS

Two key elements of arithmetical competence are computation and problem solving abilities (Das 1988). Computation involves the performance of arithmetic operations, such as addition, subtraction, multiplication and division of whole numbers, decimals and fractions and conversions between the latter. These skills are essential elements of the mathematics used by nurses in clinical practice (Pirie 1987, Roberts 1990, Hutton 1998a). The ability to solve problems involves understanding the logic of a problem and utilizing processes which involve coding of information into a meaningful whole. In relation to medication dosage problems it requires: the ability to understand a prescription chart and dispensed drug label, and to extract the important information necessary to set up the dosage problem correctly; an understanding of the difference between dispensed dosage of medication and the volume or vehicle in which that dosage comes; and the ability to place numbers correctly in a format for calculation (Roberts 1990). Clearly, both these skills are essential to ensure that patients receive correct medication dosages (Chenger et al. 1988), but their acquisition may be problematic, as we will show in the next section.

COMPUTATION ERRORS AND STUDENT CONCEPTIONS

For some years one of us (KW) has been involved in nurse education in a UK higher education institution, and has a specific interest in the teaching of biosciences and associated numeracy skills. During the early 1990s a comprehensive medication dosage calculation skills development programme was produced as part of the pre-registration Diploma in Nursing Studies curriculum. This included a comprehensive teaching programme, promotion of fundamental arithmetical skills development to replace calculator use during written assessments, and key clinical objectives aimed at development of safe administration of medications via oral and injection routes and IV infusion. Lessons and tutorials were delivered as part of 'Theory to Practice' units in the eighteen month Common- Foundation Programme (CFP). The content centered on developing the fundamental skills used for calculating common dosage problems seen in clinical nursing practice. This included conversion between SI units of weight and volume, calculation of oral medication dosages, injection dosage volumes and calculation of intravenous infusion volume and drop rates. At the end of the taught programme each student undertook a 30 point written assessment. Students were permitted to take dosage calculation formulae into the classroom as the assessment was based on professional skill development and was not a test of memory. However, students were not permitted to use calculators as they are not always available in clinical areas (Hutton 1998b). Given the nature of the skills being tested, students were required to obtain a 100% achievement score. Each was permitted three attempts at the assessment during the CFP, these being interspersed by periods of clinical practice and further tutorials. However the results consistently showed that more than 50% of students failed to achieve the requisite 100% score on the first attempt and approximately 16–33% failed to achieve the requisite score after three attempts.

Analysis of novice student's assessment papers revealed both computation and conceptual problem solving errors, the latter ranging between -5 to, in some cases, many times the correct answer. Clearly safe and accurate dosage calculation ability must be demonstrated prior to registration as a professional nurse. Therefore, prior to final UKCC registration all students at the study site were required to achieve a 100% score in written assessments, and 100% competence in dosage calculations performed in clinical practice. Moreover, the development of approaches that would assist early acquisition of these skills became a major education aim at the study site. This begins with a review of misconceptions theory.

MISCONCEPTIONS THEORY AND ITS APPLICATION IN NURSING

Research into 'misconceptions' is based on the tenet that novices' conceptions commonly differ from those of experts, especially in the fields of mathematics and science. The term 'misconception' refers to a student conception that produces a systematic pattern of errors (Smith et al. 1993). Smith et al. described the main features of misconceptions theory presented within the mathematics and science literature as: Students have misconceptions. These originate in prior learning, can be stable and widely spread among students, and can be strongly held and resistant to change. Misconceptions interfere with learning and therefore must be replaced.

However Smith et al. (1993) question this view and argue from a constructivist standpoint that mere documentation of misconceptions does not advance our understanding of learning, or of how prior knowledge is transformed into more sophisticated forms. That is as learning involves the gradual recrafting of existing knowledge, research should attempt to explain the basis of student's current conceptions, and how expert understandings develop. We believe that these premises are critical to developing clinical effectiveness in nursing, not least because as the learning of mathematics is a process of building up knowledge, a gap or a misunderstanding can deter future progress (Withnall et al. 1984). Our belief is founded upon observations of student performance during written medication dosage calculation assessments. We have noted three types of error committed by nursing students, all of which highlight student's initial conceptions in terms of the definition used by Smith et al. However, for the purposes of comparison with previous nursing studies (Pirie 1987, Shockley et al. 1989, Blais & Bath 1992), three classification areas have been adopted. These are *conceptual errors* (lacking understanding of the logic of a problem or setting the dosage calculation equation up incorrectly-see later). *Arithmetical operation errors* (misunderstanding of arithmetical operations, e.g. dividing a fraction denominator by the numerator, Fig. 1); and *computation errors* (basic errors of multiplication, division etc, Fig. 2). We are grateful to those students who consented to the reproduction of examples of error types that represented initial conceptions during written assessments. Subsequent papers explain a new system that aided 44 students to recraft these errors.

Observations of *poor computational ability* among nursing students have been extensively reported within the professional literature (Bindler & Bayne 1984, Pirie 1987, Kapborg 1992, Gillham & Chu 1995, Hilton 1999). However this problem is not unique to nursing students. Reports from the UK higher education domain indicate a perceived decline in undergraduate mathematical ability in a range of non specialist mathematics programmes (Sutherland & Pozzi 1995, Howsen et al 1995, James 1995, Edwards 1996).

Reports of these findings caused concern among education and clinical nursing staff. Therefore a fundamental numeracy assessment was devised by the school and incorporated into the selection process.

THE DIAGNOSTIC TESTING OF COMPUTATIONAL ABILITY

Identification and documentation of misconceptions in a range of domains has become a major task for research in mathematics and science learning (Smith et al. 1993). Concerns regarding the mathematical abilities of nurses have been expressed within the nursing profession, with calls for all prospective nursing students to be 'pre-tested' to ascertain their levels of mathematical ability (Miller 1993). A survey of 32 colleges of nursing in England, UK reported that five colleges tested mathematics ability at interview and eight colleges required a 'C' grade GCSE qualification in mathe-

Drug Name:	Prescribed Dose:	Dispensed Dose:	Contained in:	How many ml
Haloperidol injection	2 mg	10 mg	2 ml ampoule	Answer

Please show your calculations / workings here:

$$\frac{\cancel{2}^{1} \times 2}{\cancel{10}\,5} \quad \frac{2}{5} = 2\overline{)5.00}^{\,2.5}$$

Answer: 2.5ml

Here the student has correctly set up the problem and cancelled the equation to 2/5; but has then incorrectly divided the denominator by the numerator. This resulting in an answer of 2.5 ml (correct answer 0.4 ml). This representing over 6 times the prescribed dose.

Fig. 1 An arithmetical operation error.

I.V. Fluid Name:	Prescribed Volume:	Infusion Time:	Number of drops/ml delivered by administration set:
Sodium Chloride 0.9%	1000 ml	8 hours	20 drops / ml

a. How many millilitres per hour **Answer**

Please show your calculations/workings here

225
8)1000

225

Here the student has set the problem up correctly, but has made a simple arithmetical error of division, i.e. has computed 10 divided by 8, as 2 remainder 2. Resulting in an answer of 225 ml/hour (correct answer 125 ml/hour), representing an infusion time of less than 4.5 hours, as opposed to the required 8 hours.

Fig. 2 Computation error.

Table 1 Percentage of sstudents achieving 100% (total 30/30) required score

Group	First attempt	Mean score	SD	Second attempt	Mean score	SD	Third attempt	Mean score	SD
1 (n = 93)	44%	27.0	3.62	68%	28.2	3.19	78%	28.6	3.00
2 (n = 96)	41%	26.9	3.97	57%	27.4	3.81	67%	27.6	3.67
3 (n = 100)	43%	27.0	3.75	73%	27.7	2.98	84%	28.1	2.63
4 (n = 103)	38%	26.7	3.87	61%	27.6	3.77	82%	28.4	3.31

matics or science (Hilton 1999). However, reliance upon students possession of a 'C' grade at GCSE level mathematics may not be appropriate, as it may not be an accurate indicator of competency in basic arithmetic or the type of mathematics used in nursing (Hutton 1998b, Hilton 1999).

At the study site the introduction of a numeracy test on selection day was aimed at identifying prospective nursing students' ability to perform basic arithmetical computations without the aid of a calculator. The 40 point assessment was divided into 10 four point sections and covered arithmetical operations identified in a range of taxonomies of mathematics used by nurses (Pirie 1987, Roberts 1990, Hutton 1998a).

This included a test of basic addition, subtraction, multiplication, division, conversion between fractions and decimals, multiple computations of whole numbers, and conversions between SI units of weight and volume. The test was piloted among students who had previously passed the college dosage calculation assessment and a minimum achievement score of 24/40 (60%) was set. This was consistent at the time with other minimum achievement levels reported in the UK nursing literature for this type of selection test (Hek 1994). Following introduction of the test there was a moderate improvement in group scores. However, lecturers continued to be perplexed by the widespread presence of computation errors during written fundamental dosage calculation assessments. Table 1 provides an example of four cohorts of student results over a 2 year period following introduction of the numeracy test.

At this point it was decided to undertake a more detailed investigation of the type of errors committed by students during the numeracy assessment undertaken at selection. A 40% sample of students were randomly selected from a typical cohort (n=44). Analysis of the selection numeracy test for the sample is summarised in Table 2.

When this was compared to previous cohorts a similar pattern was revealed. Hence it became clear that students were entering the nursing programme prone to 'misconceptions' of which lecturers were unaware. For example, students who achieved 60% (24/40) could effectively commit 16 errors and pass the test. Yet many of these errors were in arithmetical skills that were critical to the calculation of dosage problems encountered in clinical practice.

Table 2 Number of critical errors committed by students ($n = 44$) on the numeracy test

Computation skill tested (specific to dosage calculations)	Number of students committing 1–3 errors	Number of students committing 4 errors	Total number of errors committed
Multiplication of whole numbers	19	0	19
Division of whole numbers	32	1	52
$\frac{A \times B}{C}$	12	2	22
Conversion of fractions to decimals	19	3	48
Conversions of SI units of weight (milligrams to micrograms etc)	36	7	91
Conversion of SI units of volume (litres to millilitres etc)	9	1	13

This led to the conclusion that the content, analysis and scoring method of such numeracy tests must be skill-specific, and this is currently being researched at the study site. However, it is essential to make students aware that such tests are not to determine how weak they are at mathematics, but to allow the design of a meaningful teaching programme based on their current capabilities. During interviews with students many expressed feelings of not fully understanding basic computation methods and of school mathematics not having much relevance to everyday needs. One student's comment was typical of that expressed by many students

> ...I found maths at school very hard...It was things like trigonometry and well I don't think it's very necessary for modern day use...I mean you don't sit around thinking...Oh I wonder how I can use trigonometry to work out the length of a side of this triangle...I think schools should listen to what Tony Blair is saying and go back to basics ... because my basic maths is just not very good at all.

We recognize that mathematical skills involving trigonometry and calculus etc. are essential to a number of disciplines. Nevertheless the reported view of students at the study site was echoed by the School Curriculum and Assessment Authority (1997) report on 'Literacy and numeracy in the workplace'. The report stated that

> Employers were dissatisfied with young employees' mental arithmetic skills, and their tendency to accept calculator output uncritically without doing a rough estimation check. Employees felt that much school mathematics was too theoretical, and much of what is covered in mathematics syllabuses is never used in employment (SCAA 1997, p.3)

Recognition of the level of mathematical ability demonstrated by a range of current undergraduates in the UK has been reported by the Open Learning Foundation (Edwards 1996). The OLF examined university courses in which mathematics was taught as a non-specialist subject, e.g. engineering and business studies. A common impression reported in the survey was that many courses had to 'take a step back' from the mathematical starting point they would have used several years ago. Among the key recommendations was that assessment questions should be designed so that wrong answers reveal common weaknesses and areas of misconception. However, there was recognition that to alter the *standard* of course content to match the capability of incoming students, would have far reaching ramifications. This latter point is of critical relevance to nursing, as the United Kingdom Central Council (UKCC), for Nursing, Midwifery and Health Visiting (1986) state that

> registration protects the public by indicating that the practitioner is safe and competent to practice.

This being affirmed through the learner's achievement of the outcomes designated in the Nurses, Midwives and Health Visitors Approval Order, Rule 18A (2) (1989), via which the Welsh National Board (2000), state that as part criteria for assessment of safety, nursing students must demonstrate ability in

> calculation, handling, administration and storage of drugs.

Clearly the development of such skills cannot be left to chance and hence all efforts are required to both develop and assess relevant skills achievement among nursing students.

In the general higher education domain there is evidence of many universities using diagnostic testing of mathematical ability, with suggestions that more positive ways should be found to respond to the abilities of many incoming students (Edwards 1996). Moreover those involved in higher education need to consider further their provision for incoming students – particularly in the short-term, before changes can be made at secondary level (Howson Report 1995, cited by Edwards 1996). Subsequently as we will explore in future papers it is our experience that:

(a) Some students require additional tutorial time to fully develop computation skills.

(b) Assessment of arithmetical ability should initially centre upon diagnosis of student's initial conceptions and not merely involve knowledge based tests.

(c) A sensitive and stigma free support network assists students to develop, recraft and apply these skills to professional nursing practice.

At this point we now move on from computation skills to the development of medication dosage problem understanding.

CONCEPTUAL PROBLEMS AND THE IMPACT OF DIDACTIC TEACHING METHODS

During the acquisition of dosage calculation skills nursing students are required to develop an understanding of both the 'real life' problems encountered in clinical nursing practice, i.e. the clinical context and underpinning logic of the dosage calculation problem to be solved; and the abstract word problems, formulae and equations that are used to represent, explain and solve these problems. This process is complicated by the so called theory-practice divide. That is the often described mis-match between classroom or textbook theory and the reality of what exists in clinical practice (Bendall 1976, Melia 1981, Howkins 1994, Prowse 1996). In a professional context the higher education process of 'front-loading', that is exposing students to theory before practice, has been criticised for teaching theory out of context (Schon 1983, Eraut 1994). Conversely, to send novice nursing students out into a new world of clinical nursing practice, with no formal preparation would arguably represent 'blind practice'. Ultimately this forms a rather spurious argument, as by definition where theory precedes experience, or where experience precedes theory, *a theory-practice divide will be created*. When this study began, classroom teaching at the study site was largely by means of didactic, i.e. formal instruction methods using word problems and mathematical abstractions in the form of dosage calculation formulae. Word problems *attempt* to provide context by using words to describe a real situation –

Box 1 A typical medication dosage word problem.

A doctor has prescribed Morphine Sulphate 2.5 mg, to be administered via injection. The pharmacy has dispensed 10 mg of the drug contained in a 1 ml ampoule. How many millilitres would you draw up into a syringe and inject?

for example see Box 1.

Students were taught the use of equations derived from dosage calculation formulae to solve these word problems. A typical example of a dosage

Box 2 A typical formula used to solve injection dosage problems.

$$\frac{\text{Prescribed dose} \times \text{Volume dispensed dose contained in}}{\text{Dispensed dose}} = \text{Volume to be injected}$$

formula used at the study site is shown in Box 2:

Using the above formula the word problem described in Box 1 would be set up and solved by substitution of the given values in the equation in

Box 3 Equation used to solve the word problem described in Box 1.

$$\frac{2.5 \times 1}{10} = 0.25 \text{ ml}$$

Box 3:

However, following exposure to this process a range of students commonly misunderstood the logic of the problem they were attempting to solve. This was manifested as a misconception we have termed a *conceptual error*. A typical example derived from the formula and equation illustrated in Boxes 2 and 3 is shown in Figure 3:

Hence in addition to evidence of computation errors, there were also instances of a marked misunderstanding of the basic word problems and formulae. This phenomenon was also noted by Hutton (1998a) who found that nursing students seemed to have difficulty in conceptualizing problems and forming a numerical calculation from the words. Similar findings have been reported among nursing undergraduates in the USA, where in an analysis of errors committed on a written dosage calculation assessment, 68% were conceptual in origin. This took the form of students not knowing how to set the problem up correctly or in what form to administer the medication (Blais & Bath 1992). These conceptual errors were of concern to us, as registered nurses must be able to both extract and appropriately apply the key *written information* contained in prescription charts and medication containers/ampoules.

However, observations made during tutorials involving more than 200 CFP and branch students who had been consistently exposed to didactic

Drug Name:	**Prescribed Dose:**	**Dispensed Dose:**	**Contained in:**	**How many ml**
Morphine Sulphate	**2.5 mg**	**10 mg**	**1 ml ampoule**	**Answer**

Please show your calculations / workings here:

$$\frac{1 \times 10}{2.5} = \frac{\cancel{10}}{\cancel{2.5}} \quad \frac{4}{1}$$

4ml

Here the student has failed to grasp the logic of the problem to be solved and has incorrectly set the equation up as dispensed volume (1 ml) multiplied by the dispensed dose (10 mg); the product of which has been divided by the prescribed dose (2.5 mg). This resulting in an answer of 4 ml (correct answer 0.25 ml). This representing 16 times the correct answer (a dose of 40 mg). This was all the more worrying as although students were not provided with formula sheets, they were permitted to *take their understanding of the formula* into the assessment with them.

Fig. 3 Conceptual problem solving error.

teaching methods, provided us with an insight into the difficulties encountered by these students. A striking observation was that many students had at best, vague conceptual models of the concrete 'real life' elements described in dosage calculation word problems and arithmetical formulae. A comment by one student illustrates the point:

> ...there were words like prescribed over dispensed ... and then suddenly we were using numbers and a formula ... but I couldn't see where they came from ... and it wasn't just me ... we were sat there and everybody was looking at each other ... and there were blinkers coming up with lots of people.

Following successful completion of the assessment, a number of students revealed that they felt that the lesson had prepared them to pass the test, but was not so easy to link with clinical practice. This view was supported by a previous study, which reported strong feelings among 19 newly qualified registered nurses regarding both reality shock and concerns regarding undertaking medication administration duties (Rees 1998). Similarly Hutton (1998b) reported that many students in her sample suggested that classroom mathematics did not make sense until used in the clinical area. These findings support claims from general education sources suggesting that manipulation of abstract symbols in isolation divorces mathematical operations from reality; while conversely the presence of physical objects in the environment renders numerical tasks more meaningful for some learners (Reed & Lave 1981, Carraher et al. 1985, Noss et al. 1998). Again this reflects a noticeable divide between classroom taught theory and practice. There have been recommendations that schools of nursing should emphasize instruction in problem-solving that help students to conceptualize and set up problems correctly (Blais & Bath 1992, Cartwright 1996). However to date there has been little attempt to suggest how this might be achieved.

APPLICATION OF CONSTRUCTIVIST THEORY

Following recognition of the limitations of a didactic transmission model of education, we began to use a range of constructivist approaches to learning. The basic premise of constructivism is that our sensations, perceptions and knowledge cannot exist outside of our minds (Hendry et al. 1999); and that human knowledge develops as an active, constructive process, through which individuals build more advanced knowledge from prior under-

If I use the word 'dog', what comes into your mind?...I suspect that what appears is not the 'word' DOG but rather a visual representation of a furry quadruped with two ears, a tail and a cold nose.

Fig. 4

standings (Smith et al. 1994, Fox 1997). Thus the first principle of constructivism is that knowledge is *not passively received* but *actively built up by the individual* (von Glaserfeld 1989). In the constructivist view of von Glaserfeld the term *concept* refers to 'any structure that has been abstracted from the process of experiential construction ... and which must be stable enough to be *re*-presented in the absence of perceptual input' (von Glaserfeld 1987, p. 282). Consider our example in Figure 4:

On the basis of examples such as that illustrated in Figure 4 we drew on the comprehensive work of von Glaserfeld (1987) and Bruner (1975) to develop an hypothesis regarding why students were committing the type of conceptual error illustrated in Figure 3. That is when initially learning concepts such as 'dog' or 'apple', von Glaserfeld's theory suggests that we learn to associate 'apples', etc that we have experienced in our environment (experiential field), with the words as they appear as a recurrent sound pattern or written word. Critical to this notion of constructing concepts is that before we can be said to have acquired the meaning of the word 'apple' or 'dog' or 'ampoule' or 'weight : volume ratio' etc.; that we must acquire the ability to mentally *imagine or visualize* that entity which we have associated with the word, even when that entity is not actually present in our immediate environment. However, we began to recognize that for many learners the use of a didactic transmission method of teaching had failed to assist them to construct a conceptual model which represented a semantic connection between the words used in formulae, and the prescription charts and ampoules etc, experienced in clinical practice. Subsequently, we hypothesized that for these learners, certain elements of the word problems and formulae became 'meaningless'; a recipe approach to setting up dosage calculation problems was adopted; and where this approach failed or became confused a conceptual error occurred.

Therefore we drew on Bruner's (1975) learning theory, and hypothesized that if word problems, dosage calculation formulae and the equations that are derived from them were to prove useful to a range of novice learners at the study site, then they had to be assisted to:

1. Construct conceptual models of the *'real'* iconic prescription charts, drug ampoules and drug label information etc. that are *represented by words in dosage calculation formulae*.
2. Identify and extract the key (*number symbol*) information contained within the charts and drug labels.
3. Substitute the extracted *number symbols* for the 'iconic' features and the words that represent them in the dosage calculation formula, and correctly locate them within an *equation* for computation.
4. Correctly *compute* the numerical information located within the *equation*.

Consequently we further hypothesized that if we were to assist learners to narrow the *theory-practice divide*, then we must develop learning environments that assist them to form these conceptual models. In part 2 of this series we will more fully explore the principles of a range of constructivist approaches and illustrate how these principles underpinned the development of a computer-based 'authentic world' learning environment. Finally, in the third part of this series we evaluate the impact of this system upon the learning and practice of dosage calculation skills in both college and clinical settings.

CONCLUSION

It is crucial that nurses possess the knowledge and skills to perform computations and the more complex problem-solving skills involving formulae, as such skills are needed to ensure that patients receive correct medication dosages. In terms of education for clinical effectiveness it is our position that nurse educators should pay equal attention to the development of learners computation and medication dosage calculation problem-solving skills. Concerns regarding the level of mathematical ability among a range of current UK undergraduates has led to the suggestion that colleges have to 'take a step back' from the mathematical starting point they would have used several years ago. The use of diagnostic testing of arithmetical ability has been advocated within nurse education. However on the basis of findings reported in this paper, for such testing to be effective in diagnosing student's initial conceptions, then skill-specific analysis is necessary if this is to prove effective. Subsequently it is our experience that a sensitive and stigma free support network assists students to develop, recraft and apply these skills to professional nursing practice.

During the transition of the novice nursing student to clinically effective professional nurse, novices are required to develop an understanding of *both* the 'real life' dosage problems encountered in clinical nursing practice, and the classroom oriented abstract word problems, formulae and equations that are used to represent, explain and solve these problems. This process is complicated by the so called theory-practice divide. It is our position that to assist in narrowing the gap between theory and practice, and to assist in overcoming conceptual errors during dosage calculation problem solving, that a constructivist approach provides a useful foundation for novice learners. The approach adopted at the study site will be explored in Parts 2 and 3 of this series.

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The strive for clinical effectiveness in medication dosage calculation problem-solving skills: the role of constructivist learning theory in the design of a computer-based 'authentic world' learning environment

K. W. Weeks, P. Lyne, L. Mosely and C. Torrance

This is the second of three papers in a series describing the design and production of an 'authentic world' environment to help students as they learn medication dosage calculation skills. It begins with a brief account of the constructivist view of the role of words as 'containers of meaning'. This shows that didactic teaching methods may be founded on assumptions which deny the relationship between words and the concepts constructed by each individual as a result of their prior experience. It is suggested that problems experienced by students when taught in this way constitute a very real theory practice divide and may be explained in terms of constructivist learning theory.

A fuller explanation of the range of constructivist theories follows and we show how thinking which arose in a number of educational fields, including mathematics education, influenced the adoption of a constructivist approach to the teaching and learning of practical mathematics in nursing.

This led to the need to develop a suitable learning environment in which students could acquire medication dosage problem-solving skills. The main body of the paper provides an illustrated account of a prototype computer based 'authentic world' environment and the educational theories which informed and shaped its development. The evaluation of this system in both educational and clinical settings is the subject of the third and final paper in this series.

Keywords: constructivism, bridging the theory-practice divide, computer based learning, drug errors, dosage calculation

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INTRODUCTION

Part 1 of this series of papers described the computation and conceptual problem solving errors shown by nursing students who were taught medication dosage calculation skills through traditional methods (Weeks et al. 2000). The paper emphasized the observation that many novice nursing students had

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only vague conceptual models of the 'real-life' dosage problems seen in clinical practice and described by dosage calculation 'word problems'. This led to the suggestion that if learners were to become safe and clinically effective practitioners in this regard then they needed to be helped to construct much stronger conceptual models of, and links between, both real-life dosage problems, and the word-based formulae and number based equations used to solve these problems.

The current paper (Part 2 of the series) describes how this suggestion led to the development of a computer based learning environment. This was designed to help learners construct conceptual models of the real life 'iconic features' of dosage problems, and the word and number 'symbols' used in dosage calculation formulae and equations. The emergent nature of this program and the theoretical perspectives which informed its design are presented in parallel. This discussion acts as a backdrop to Part 3 of the series of papers, which provides an evaluation of this system in both the college and clinical setting; showing how the use of the program was successful in helping students to overcome conceptual difficulties that they, like so many others experienced.

THE NEED FOR AN ALTERNATIVE APPROACH TO TEACHING CALCULATION SKILLS

Increased understanding of the nature of the problems experienced by students as they sought to improve their calculation skills led to the recognition that a change of emphasis in teaching and learning was necessary. We begin by indicating some assumptions underlying the traditional methods originally used and then describe the problems which students encountered.

Traditional methods of teaching medication dosage-calculation skills commonly rely on words to convey the problems which students are required to solve during their professional education. The use of written and spoken words is such a universal feature of human communication that we rarely question our assumptions about the process. As von Glaserfeld argues:

> When we understand what we read, we gain the impression that we have 'grasped' the meaning of the printed words, and we come to believe that this meaning was in the words and that we extracted it like kernels out of their shells. We may even say that a particular meaning is the 'content' of a word or a text. (von Glaserfeld 1987, p.316).

This author claims that the notion of words as 'containers of meaning', in which the writer or speaker 'conveys' meaning to readers and listeners is extraordinarily strong and seems so natural that we are reluctant to question it. However, in his view this is a misguided notion. For each one of us, the meaning of a concept is an abstraction which we have made from 'real life' experiences. That is to say concepts are:

> ...subjective in origin and reside in a subject's head, not in the word, which because of an association, has the power to call up, in each of us, our own subjective representation. (von Glaserfeld 1987, p.317).

In Part 1 of the series we provided a simple example to illustrate this point. We suggested that hearing the word 'dog' calls to mind not the word itself but an individual representation of a furry quadruped based on prior experience of animals of this class. This construct resides within the individual's mind, and a semantic connection exists between the word (in any language used by that individual) and the concept. Reading or hearing the word calls up a subjective representation of that concept. Thus, whilst the word can be used to transmit some information between individuals it cannot, of itself, bring about the sharing of experientially constructed concepts.

The notion that words can act as containers or conveyancers of meaning in the fullest sense lies at the heart of the belief that knowledge can be 'transmitted' from one person to another, without consideration of the nature of the concepts held by participants in the interchange.

Difficulties experienced by students

In Part 1 of the series we suggested that student problems were not helped by the use of traditional (didactic transmission) teaching methods, using words for which students did not have adequate conceptual models. For many students, these words effectively constituted a 'foreign language', with no semantic link to recognisable concepts. One student's evaluation of teaching involving word problems bears this out:

> I felt like I was back in school. I hated math's then. I just didn't understand what pie (*sic*) and all those numbers meant in real life and this is just the same. I didn't understand it then and I still don't understand it now. I just hate these drug calculation sessions. I feel sick every time I know one is coming up.

Many other students made similar comments and frequently they included phrases such as: 'I couldn't *see* what he was saying...', 'I just don't *see* what she was getting at' or 'no I still don't *see* it...'. The significance of the use of such phrases was not recognized for some time. That is we took these comments as colloquialisms and quite frankly, ignored them. However, during a series of in depth tutorials we began to recognise that many learners could not in fact mentally '*see*', or represent these concepts to themselves. This we hypothesized was related to either their limited experiences of objects and events in real world practice, or conversely because the students had failed to link previous relevant clinical experiences with the lesson content being presented to them. Since these semantic connections form the link between 'abstract' formulae and equations and the key features of clinical dosage calculation problems, this inability to 'see' the latter assumed a new importance.

Discussions were held with other lecturers who were involved with teaching medication dose calculation skills. It transpired that they used similar terminology to describe how they 'visualized' calculated dosages. For example one explained that if an answer to an injection problem was 'one millilitre of a dispensed two millilitre ampoule', then she 'saw half an ampoule' in her mind. That is as experienced clinical practitioners we had all constructed our own conceptual models of the problems to be solved. However, difficulties arose when attempts were made to 'transmit' these concepts via word problems, to students who had yet to construct their own adequate models and/or form semantic connections with the words and numbers used to represent them in formulae and equations. Subsequently, the resultant difficulties created a very real theory practice divide for these students.

In her doctoral study Hutton (1998) found that competence in nursing mathematics develops through experiential learning in clinical areas, and development of a 'common sense' knowing when answers are sensible. She recommended that classroom based sessions should include realistic problems taken from relevant clinical settings, to reinforce common sense learning from the earliest possible time. Similarly, our findings strongly suggested the need to assist novice learners to construct a bridge between authentic features of clinical practice and classroom based abstractions; and thus narrow the theory–practice divide by setting a strong foundation early in the education process. It was clear that, in order to achieve this aim a change of approach to teaching and learning related to mathematical abstraction was required. In the following section we present our view of selected aspects of educational theory which underpin the constructivist approach which was selected and used to inform the development of a new teaching program.

SELECTION OF A CONSTRUCTIVIST APPROACH

Reese and Overton (1970) grouped general learning theories into two developmental models termed the *mechanistic* and *organismic* world views. The *mechanistic* model underpins a behaviourist approach to learning and represent it as a series of highly structured 'learned responses'. Such an approach informed the didactic transmission model used for the teaching of dosage calculation skills when this work began. In contrast the *organismic* model places emphasis upon the *whole* as opposed to the sum of the individual mechanical parts, with the individual being viewed as an 'intrinsically active organism', rather than simply reacting to stimuli from the environment. In terms of learning, the emphasis here is placed on the role of experience in facilitating the course of development. This is fundamental to a range of perspectives which share the term 'constructivism'.

In the literature which deals specifically with mathematics education, two broad philosophies are apparent, i.e., the absolutist and fallibilist approaches. Threlfall (1995, p.19) drew an analogy between these two philosophies and the behaviorist and constructivist education approaches respectively, i.e.:

Absolutist teaching
behaviourist approach
clear and coherent presentation
pupil practice and exercises
emphasis on 'content'
discouragement of discussion

Fallibilist teaching
constructivist approach
self discovery
real-world examples and problems
emphasis on 'process'
encouragement of discussion

Ernest (1995a) has argued that the absolutist philosophy of mathematics views the subject as a body of abstract knowledge that is both value- and culture-free, and which is inaccessible to all but those with a 'mathematical mind'. From a cultural perspective this approach promotes 'separated values'. It may be that for those individuals who move into the higher realms of mathematics this is possibly the only way to achieve the necessary level of mathematical sophistication. But for the ordinary user of basic mathematics in everyday life, something else is needed. Ernest (1995a) has argued that the fallibilist philosophy of mathematics education emphasizes the human side of mathematics, its relation to real life situations, and a cultural perspective that promotes 'connected values'. In so doing, it relates closely to the set of assumptions on which constructivist learning theory is based.

Constructivism is a term which encompasses several related perspectives. Rather than exploring the differences between these perspectives we chose to focus on their commonalities, agreeing with the view of Ernest (1995b) that when considering these varying perspectives '...there is the risk of wasting time by worrying over the minutiae of differences (p.459)'. We therefore drew on constructivist ideas from diverse sources, including the worlds of genral and mathematics education and synthesized them for application in the world of nursing.

Constructivism is based on the fundamental assumption that our sensations, perceptions and knowledge cannot exist outside of our minds (Hendry *et al* 1999, p.359). It proposes that understanding is *actively* built by the individual rather than being built up from *received* pieces of knowledge (von Glaserfeld 1989, Ernest 1997). As a learning theory it described understanding as the building of mental structures, and the restructuring of existing mental structures to accommodate new experiences.

von Glaserfeld (1987) links learning to the adaptation which is necessary for survival in a world of constraints. This reflects the Darwinian view of adaptation as central to evolution via natural selection. Species who failed to survive did so because their biological make-up was not adapted over time to meet the changing demands of the environment.

Fortunately in a cognitive context people can adjust and adapt to their environment through the constant construction and modification of knowledge regarding 'their world'. A major function of education is to facilitate this process in learners. In the case of education of nurses for safe and effective practice, the task is to organise students' experiences in such a way that they can adapt to the demands of their new world of professional nursing practice. Exploration of constructivist theories demonstrated their relevance to the problem in hand and, therefore, they were selected as the basis for an alternative approach to the teaching and learning of calculation skills. In order to produce an interactive environment for learning, the decision was taken to employ computer technology. Specification of the system to be developed required a more detailed exploration of specific aspects of learning theory. These will be described next.

SPECIFICATION OF THE LEARNING ENVIRONMENT

The scope of the present paper does not permit a complete description of the elements included in the specifications. Three key elements will be presented, showing how they were derived from theories based on constructivist principles. In each case, they are illustrated by examples of screen shots from the prototype learning environment which was eventually produced and evaluated in use.

The construction of knowledge into schemata

Constructivism suggests that experience is not stored as a basket full of facts. Rather it is organized in schemata (a schema is a unit of organised information). These are active mental models, that can both 'modify' and be 'modified by' experience (Deforges 1997). Piaget (1954, 1983) described the critical process of changing or up-dating the mental model experienced by the individual. This process is based upon the learner experiencing 'disequilibrium', that is when an experience fails to fit the existing knowledge system. He recognized two fundamental cognitive processes that work in a reciprocal fashion: *-assimilation* and *-accommodation*. The first is a process of incorporating new information into an already existing cognitive structure and the second the construction of a new cognitive structure to incorporate the new information.

In the early stages of the present study it was observed that approximately 40% of nursing students in each cohort appeared to adapt early to the experience of learning dosage calculation skills via didactic methods and word problems. However, between 16–33% of learners continued to experience difficulties in assimilating this information throughout the Common Foundation Programme (CFP) and into the branch programmes (Weeks et al. 2000).

The efficacy with which schemata developed, was essentially dependent upon the ability of the student to build the concept from both 'new' and 'previously constructed', but unrelated cognitive structures. This process highlights a fundamental tenet of Piaget's theory, i.e. that if learners are to adapt to a new environment then both assimilation and accommodation must occur, and the learning environment should be designed to facilitate this process.

Piaget argued that the construction of schemata follows a developmental course. In the stage of *concrete operations*, children aged between 7 and 11 years make use of 'reversible operations' such as addition, multiplication, classification and seriation but find it difficult to abstract away from experiences to general rules. They need the help of concrete materials to use their power of reasoning effectively. In the final stage of *formal operational thinking*, which Piaget found appearing from about the age of 12 years, children can make use of very general and abstract systems of ideas. The chronology initially proposed by Piaget has been questioned, and authors such as Denvir et al (1983) have described how this chronology of intellectual development is not a universal feature of all pupils in secondary school. The early empirical findings of the present study suggested that a range of students entering the nursing programme experienced varying degrees of difficulty when dealing with mathematical abstractions rather than 'real world' concrete features. For example, one area where many students showed problems in constructing schemata was in the development of a conceptual model for SI units of weight. Most people entered the nursing programme with effective schemata for SI units of volume and the relationships between them (litres and millilitres etc.). But very few had pre-existing schemata for dealing with SI units of weight (e.g. gram, mg, mcg etc.). This difficulty revealed itself in some of the most bizarre errors committed by students during assessments, and we hypothesised that this largely centered upon their inability to mentally visualize the difference between the relative 'mass quantity' of these SI units. It therefore appeared likely that the formation of schemata was hampered by students' inability to create representations of information entities. Clearly, an important requirement for the system was that it should aid the learner to construct necessary schemata.

Modes of representation

The work of Bruner (1975, 1978) and Collins et al. (1989) was used to further inform the specification of the prototype.

Bruner's work was influenced by Piaget, and reflects the stages of development described by Piaget. Bruner suggests that the construction of cognitive structures occurs in three modalities through which the individual represents his or her world. The enactive mode uses representation through action. The iconic mode uses visual and mental images, and the symbolic mode uses symbols in the form of language and numbers. Bruner (1978) argued that any subject could be taught to any individual at any stage of development, if it was presented in the proper manner. In his view, individuals have a natural curiosity and a desire to become competent at various tasks. However when presented with a task which is too abstract or difficult, the individual loses interest. Bruner (1975) saw learning as an active process, in which the learner infers principles and rules and tests them out. Teachers should present work at a level that is challenging to that individual's current developmental stage. In terms of learning medication dosage calculation problem-solving skills our observations indicated that this involves:

1. Getting the requisite *imagery* of concrete 'real world' elements into the mind (e.g. prescription charts, ampoules, medication containers, tablets, infusion equipment, and relevant mass quantities of SI units of weight and volume etc.); using an iconic mode of representation.
2. Employing a *symbolic* mode of representation in the use of word problems, medication dosage calculation formulae, and arithmetical symbols and equations.

Bruner suggested that when a learner has a well-developed symbolic system, it may be possible to by-pass the enactive and iconic stages. But one does so with the risk that the learner may not possess the imagery to fall back on if his symbolic transformations fail to achieve a goal in problem solving. Our own observations supported this view, and indicated that use of 'expert' problem-solving techniques, and dosage calculation word problems in the classroom, obscured from many learners the essential imagery necessary to 'frame' the problem as featured in clinical practice. Hence on the basis of Bruner's theory it was necessary to *sensitize* the learner to the iconic elements of dosage calculation problems, and then to assist and support movement toward a symbolic mode of representation.

Support for this view comes from Backhouse et al. (1992) who suggested that even learners at the stage of Formal Operations can be expected to gain a great deal from concrete materials, when dealing with new concepts. Taking this idea further, we hypothesised that distinct from the ability to perform computations, that both novice and some more senior students may benefit from exposure to *both* iconic and symbolic elements of medication dosage problems. These considerations led into a consideration of the processes necessary to shape the learning environment.

The process of cognitive apprenticeship

In order to provide opportunities for learners, at the earliest possible stage in their careers, to form links between iconic and symbolic elements, we drew on the phenomenon of 'cognitive apprenticeship' (Collins et al. 1989). These authors coined the term to describe a method for teaching students the problem-solving skills involved in cognitive skills such as mathematics. Drawing an analogy with a traditional apprenticeship model, Collins et al. described how when learning psychomotor skills, the learner initially observes the master executing (or *modeling*) the target process. The apprentice then attempts to perform the activity with guidance and help from the master (via *coaching*). A key aspect of coaching involves:

> ...the provision of scaffolding, i.e. support in the form of reminders and help, that the apprentice requires to approximate the execution of the entire composite of skills. (Collins et al. 1989, p.456)

Support for this idea of scaffolding comes from the Russian constructivist Lev Vygotsky. Vygotsky coined the term 'zone of proximal development', to describe a level of performance that the individual cannot perform on his own. However, Vygotsky argued that learning can be 'stretched', by modelling the problem-solving process, and then supporting or 'scaffolding' the individuals extension of his current skills and knowledge to a higher level of competence (Harvard 1997). Once the learner has a grasp of the target skill, the master reduces (or *fades*) his/her participation and provides only limited hints, refinements and feedback to the learner, who then practices until achieving smooth performance of the whole skill. A critical feature of this process is the construction of a *conceptual model* of the target skill for the purposes of:

1. Providing learners with an advanced organizer for their initial attempts to execute a complex skill. This allows the learner to concentrate more attention on execution than would otherwise be possible.
2. Providing an interpretive structure for making sense of the feedback, hints, and corrections from the master during interactive coaching sessions.

3. Providing an internalized guide for the period of relatively independent practice by successive approximation.

Development of a conceptual model that can be continually updated via further observation and feedback, encourages autonomy through reflection (Collins & Brown 1988), this being analogous with the changing or updating of schemata described by Piaget. However, whereas psycho-motor skills are visible, this is not the case with cognitive skills taught in the classroom. Thus, in line with our observations, when taught via didactic methods and word problems, students do not have access to the conceptual models and 'expert' cognitive problem-solving processes used by lecturers. A critical element of cognitive apprenticeship requires the externalisation of processes that are usually carried out internally. That is tacit cognitive and metacognitive processes need to be brought into the open, where they can be observed by learners. In order to do this Collins et al. (1989) described the process of abstracted replay, i.e. the focusing of students' observations and comparisons directly on the determining features of their own and an expert's performance, through modeling, coaching and fading. These processes were therefore included in the specification.

On the basis of this increased understanding of the characterization of the learning activities required, the system developed took the form of an 'authentic world' learning environment. The specification for this is shown in Figure 1.

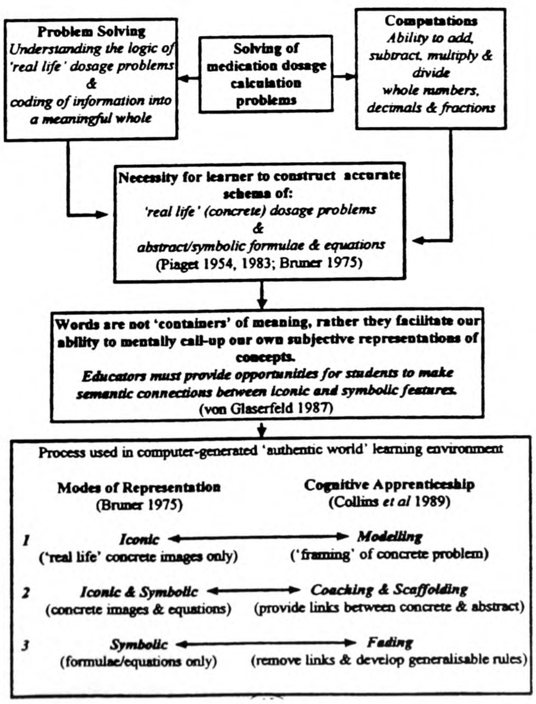

Fig. 1 Model of the design of an 'authentic world' learning environment

THE REAL WORLD ENVIRONMENT

The prototype program brought key elements of clinical practice into the classroom and directly linked them with words and mathematical abstractions. Digital photography was used to record the essential elements of real-life dosage problems and then to construct a series of computer-based and interactive montages mapping these elements onto relevant formulae and equations. The technical authoring systems used to produce the program were:

1. *Microsoft Image Composer* which is a 'Windows™' based tool that facilitates the arrangement, customization and creation of on-screen images.
2. *Illuminatus Multimedia Producer*™ (Digital Workshop 1997), which is an authoring system that allows the program designer to put together interactive and multimedia publications using the screen of a computer as the pages of an electronic book.
3. *Microsoft Visual Basic*™ which was used to create a high-performance 'Windows' type interface that acted as a 'Menu Page', with mouse operated buttons. This menu 'fronted' the program and accessed its five discrete sections:

a. Introduction
b. Conversion of SI Units of Weight and Volume
c. Calculation of Oral Medication Dosages
d. Calculation of Injection Dosages
e. Calculation of Intravenous-Infusion Volume and Drop Rates

To illustrate the nature of the prototype, we now present selected features of its operation. Figures 2 through 4 provide examples of how the program utilized the process of cognitive apprenticeship to assist movement of novice students from an iconic to a symbolic mode of reasoning.

During the stage of modelling verbal descriptions and montages in the form of colour coded digital photographs of 'real life' iconic features of dosage problems were presented to the learner. Using interactive multi-media computer-technology learners were then prompted to compute the correct number of tablets, or volume of fluid to be injected or infused, and to compare their answers with the 'expert' answer. This process was aimed at orienting the learner to the iconic 'real world' elements of dosage and infusion calculations, and development of visual schema.

During the stage of coaching, the principle of scaffolding was used to provide colour-coded links between iconic elements illustrated during the modelling phase, and abstract arithmetical symbols used in relevant dosage calculation equations. Learners were provided with a wide range of clinically-based problems (similar to that illustrated in Fig. 3), of increasing complexity, which they were prompted to solve using relevant formulae.

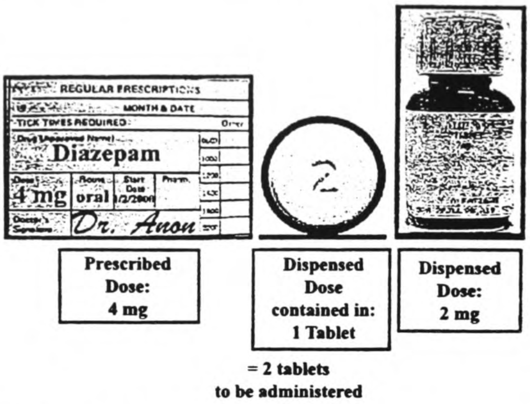

Fig. 2 Modelling

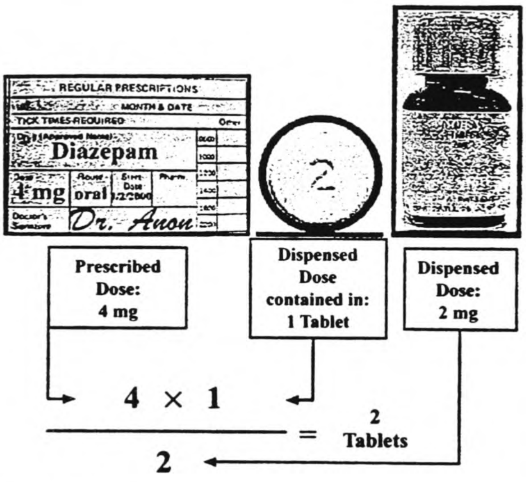

Fig. 3 Coaching

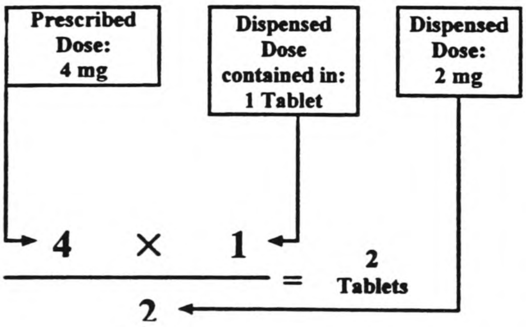

Fig. 4 Fading

During the stage of fading, all iconic elements were removed and learners were presented with a series of word problems which they were prompted to solve. This stage was aimed at development of a generalisable set of symbolic rules and schema, and required students in the absence of iconic input, to correctly extract relevant elements of word problems and to correctly locate them within an equation for calculation.

Ultimately this three stage process was aimed at equipping novice students with the cognitive skills to solve both paper-based and clinically oriented fundamental dosage calculation problems. This via sensitizing the learner to the links that exist between mathematical abstractions and the clinically oriented features they represent, and to the 'expert' problem-solving strategies that had been previously obscured from them by a transmission method of education.

The program is not advocated as a replacement for teacher-learner interactions or clinical practice, but rather to complement this process, and formed one element of a comprehensive dosage calculation teaching program. However, in some senses it might be described as a simulation and we were aware of the problem associated with the use of such ersatz activities. Ersatz being derived from the Greek for replacement, and defined as 'substitute or imitation, especially of an inferior kind'. It is important to stress that the learning environment should not be used to replace authentic activity, but rather to provide novice learners with an initial approximation of 'authentic features' situated in clinical nursing practice, and how they are represented by formulae and equations.

A simulation is an operational model, a critical dimension of which is *fidelity*, i.e. how closely the simulation imitates reality. A common error is to assume that high fidelity is always desirable, as novice learners often learn best in a simplified learning situation (Alessi 1988, Wakefield 1996). Therefore, the program was designed to approximate clinical 'reality' sufficiently to facilitate learning, whilst not being so complex as to provide extraneous stimuli which detracted from the learning process.

CONCLUSION

In this paper we have shown how awareness of the problems experienced by students learning medication dosage calculation skills brought about the search for an alternative approach to teaching and learning. An exploration of constructivist philosophy, as manifested in varied applications, led to the conclusion that this would be appropriate as the basis for such an approach. The development of a computer assisted learning environment confirmed the feasibility of using constructivist principles in this way. It was possible to derive elements of the specification from the work of a range of constructivist thinkers.

The characteristics of the prototype learning environment have been illustrated. Its effectiveness in enabling students to overcome the difficulties described in Part 1 of this series will be demonstrated in Part 3, where the results of an evaluation in both college and clinical settings are presented.

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Appendix XXXI

Computer Program Screenshots Supplied to participants

Conversions of S.I. Units - To Convert:

Litres to Millilitres

Grams to Milligrams

Milligrams to Micrograms

Multiply by 1000

Move the Decimal Point 3 PLACES to the RIGHT

Millilitres to Litres

Milligrams to Grams

Micrograms to Milligrams

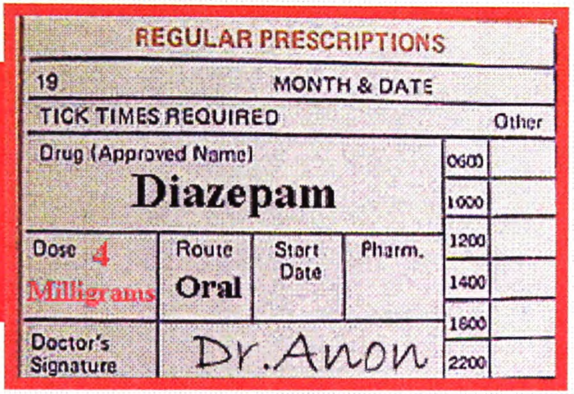
Divide by 1000

Move the Decimal Point 3 PLACES to the LEFT

Calculating Tablet & Capsule Dosages

Prescribed Dose

(e.g. 4 mg)



Dispensed Dose Contained in:

(e.g. 1 Tablet)

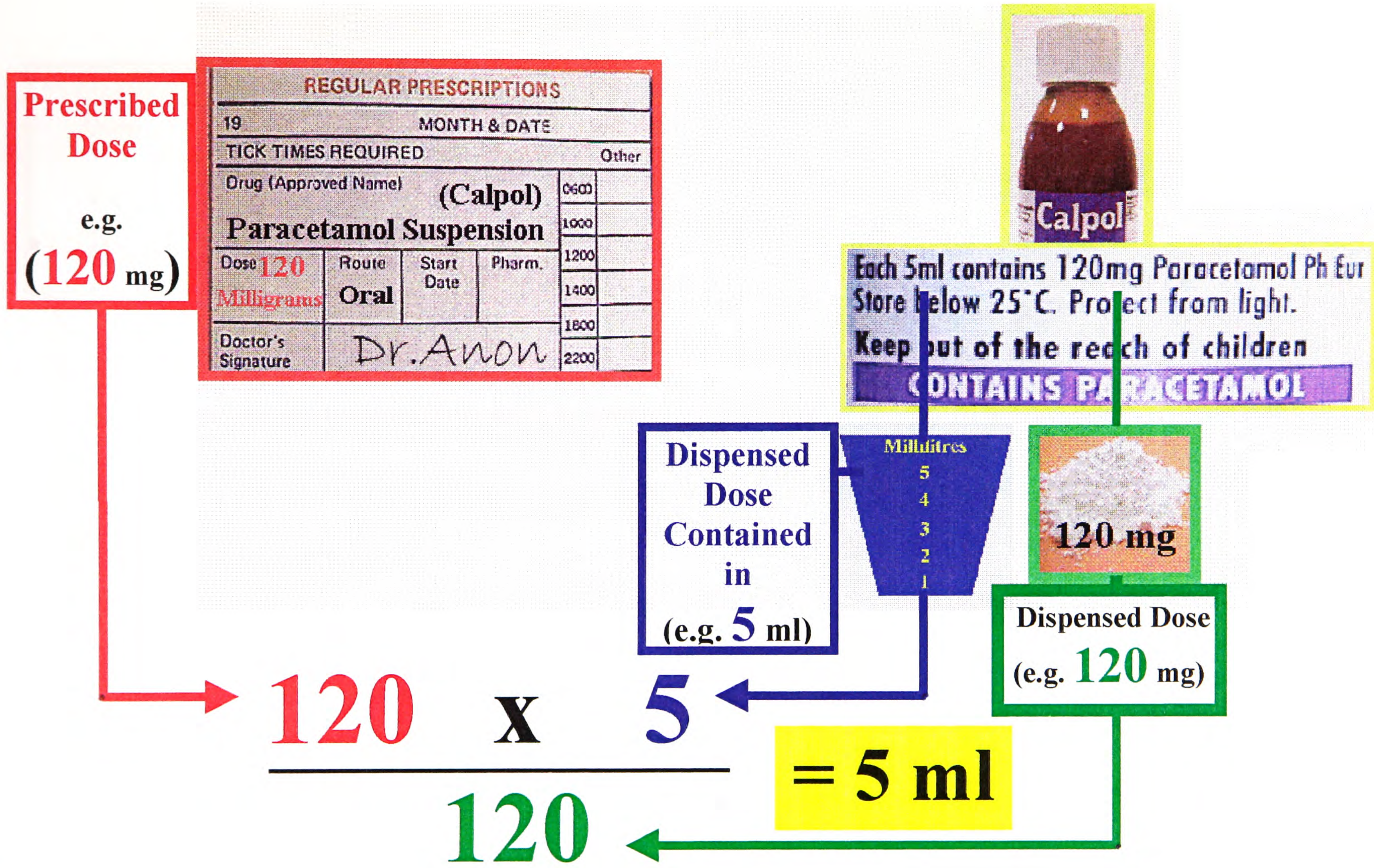
Dispensed Dose

(e.g. 2 mg)

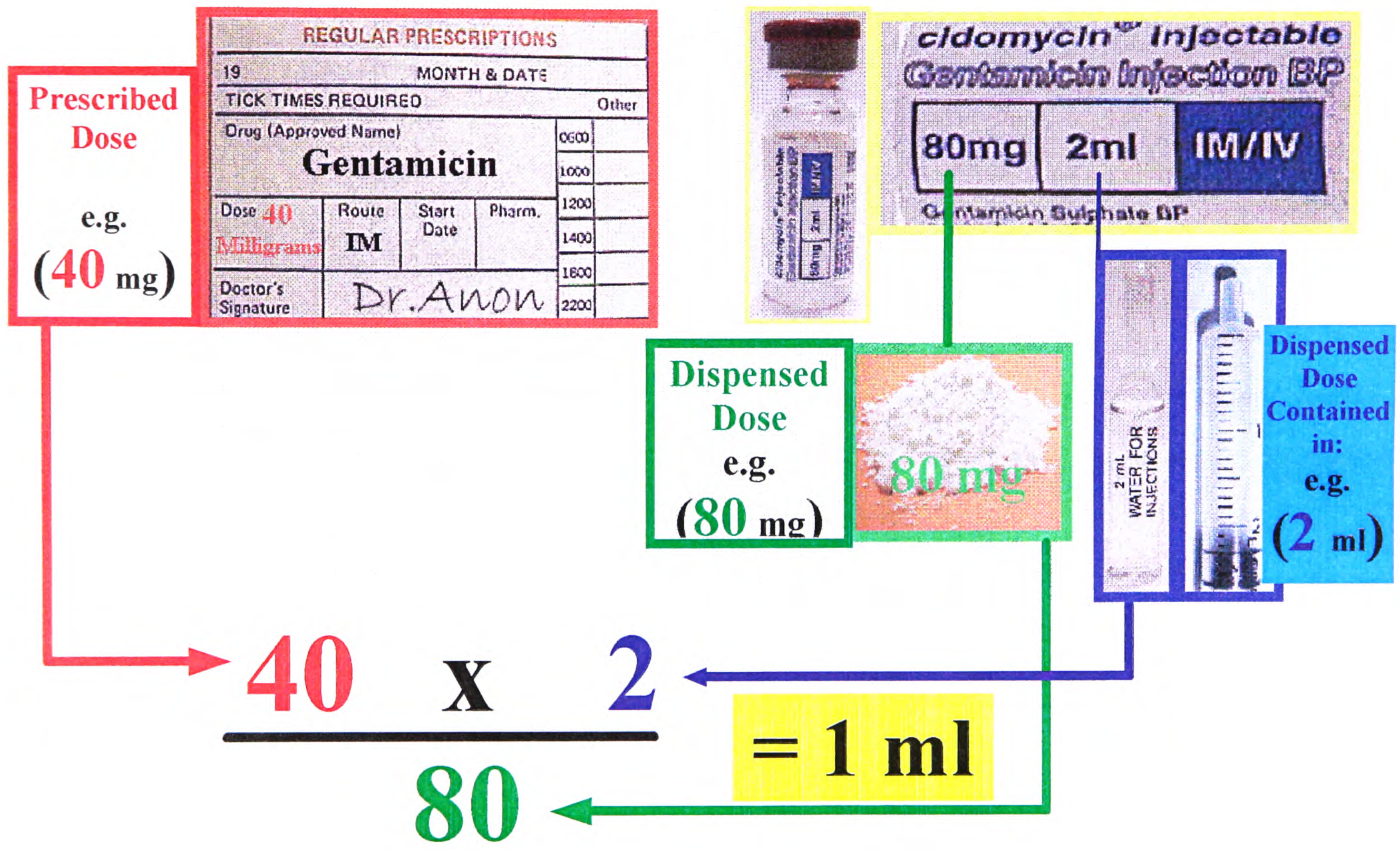
$$\frac{4 \times 1}{2}$$

= 2 Tablets

Calculation of Oral Liquid Medicine Dosages



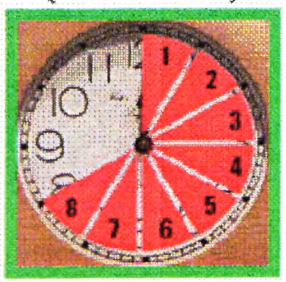
Calculation of Injection Dosages



Calculating Intra-Venous Infusion Volume & Drop Rates

A
First calculate millilitres per hour

$$\frac{\text{Prescribed Volume (ml)}}{\text{Infusion Time (Hours)}}$$



B
Calculate drops per minute

Divide the answer to Part A by:

1	3	4
If administration set delivers 60 drops/ml	If administration set delivers 20 drops/ml	If administration set delivers 15 drops/ml